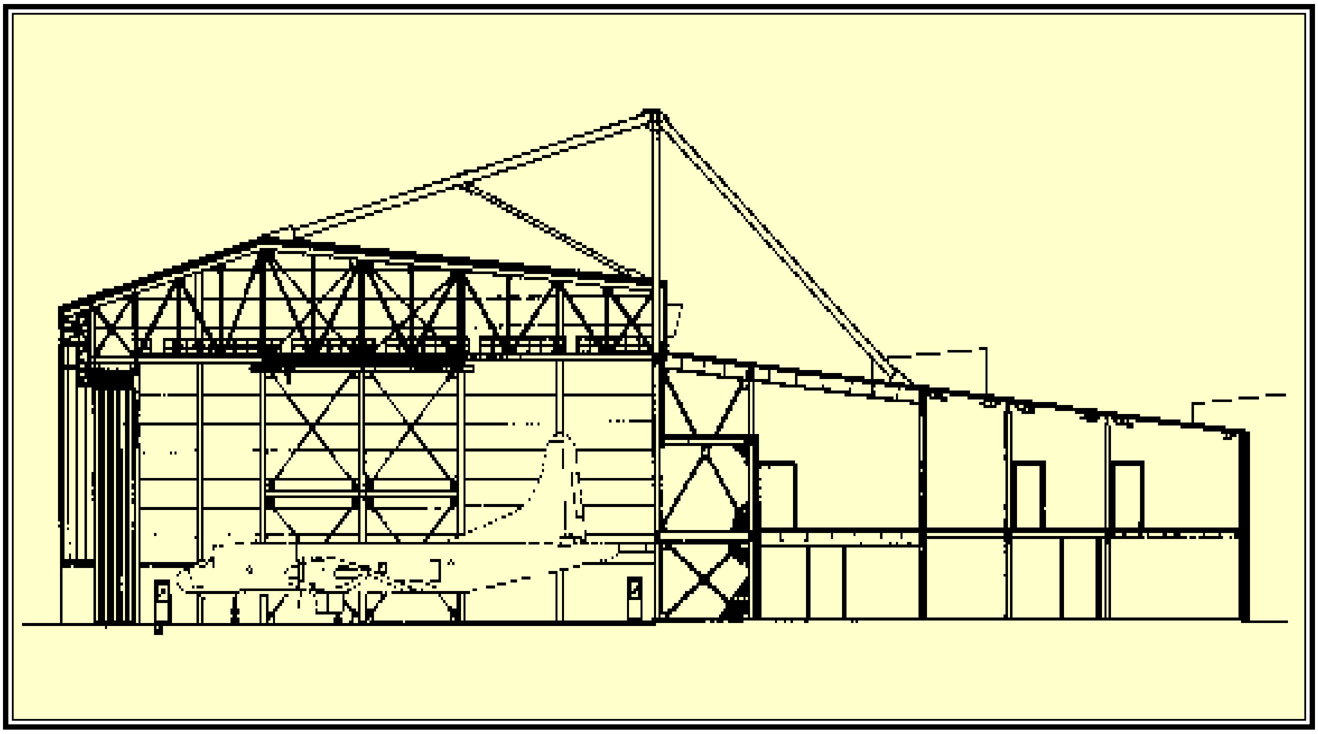
NAVY HANGAR DESIGNED TO RESIST HURRICANES

A new 600’ x 135’ clearspan hangar was designed to resist more than 1,300 kips of wind uplift

By Robert Weilacher

DESIGNING A HANGAR IN THE COASTAL REGION OF HURRICANE-PRONE FLORIDA is a daunting enough task. In addition, however, the building’s owner, the U.S. Navy, also wanted a low roof profile and minimal or concealed bracing. The program for the new hangar, which is the future home of the expanded VP-30 Anti-Submarine-Warfare squadron at the Jacksonville Naval Air Station, called for a 190,000-sq.-ft. facility, including a 500’ x 135’ clear span, five position hangar plus office and classroom space.

“It was important to integrate the building envelope with the structure to achieve economy and reduce wind resistance,” explained Jim Caulder of the Naval Facilities Engineering Command (Southern Division). Caulder, together with Philip Robbins, the officer in charge of the project, were instrumental in coordinating work between the Navy, general contractor and design team from A/E O’Kon & Company in Atlanta. O’Kon’s team was requested to design a practical roof structure that would resist gravity loads, large horizontal forces and the 80 psf



uplift forces generated by the design wind speeds acting on the structure when the doors in the 600'-long-by-40'-high hangar bay entrance are in an open position. According to design calculations, uplift forces in a storm could exceed 1,300 kips.

In addition to the project constraints reflecting economy and geometry, the O'Kon team was requested to develop a structural concept that simplified construction methods in order to reduce the time for erection. Therefore, several alternative structural methods were studied to develop an optimum design that would satisfy the project criteria, including: compatibility with aircraft clearances; ability to support a full coverage 5-ton bridge crane; rapid speed of erection; reduced steel tonnage; a low-profile architectural envelope to reduce wind forces; a structural geometry that would not interfere with strict airfield aviation clearances; low maintenance requirements; and a roof slope geometry that optimized roof drainage requirements.

The alternate concepts were analyzed using three-dimensional computer models operating

Large trusses were used to create a clearspan of 500' x 135' to accommodate five anti-submarine aircraft in a new hangar at the Jacksonville Naval Air Station.

Among the interesting design features are circular louvers, which were chosen to enhance the nautical theme at the naval base.

with STAAD-III software from Research Engineers. The concepts were graded against each other using a comparative system analysis that quantified the following: erection time; weight of steel per sq. ft.; response to hangar door deflection criteria (upward and downward deflections); height of building wind envelope; area of building surface; ability to resist large-scale horizontal torsion stresses due to design wind forces; and foundation resistance requirements for gravity, uplift and horizontal forces.

"Accurate prediction of vertical movement of the cantilever structure was critical for hangar door stability," said Steve Williams, project manager for O'Kon & Company. "With predictable deflections, the motorized door system can be made more efficient."

The selected structural system consisted of a series of five structural steel support towers, each supporting a pair of 135' stayed cantilever trusses located 24' on center with a back span of 61'. The tower frame encompasses a 24' x 24' footprint positioned at five recessed "pockets" in the rear of the hangar bay. These pockets are required for the maintenance of the electronic ASW "Stinger" empennage portion of the P-3 aircraft.

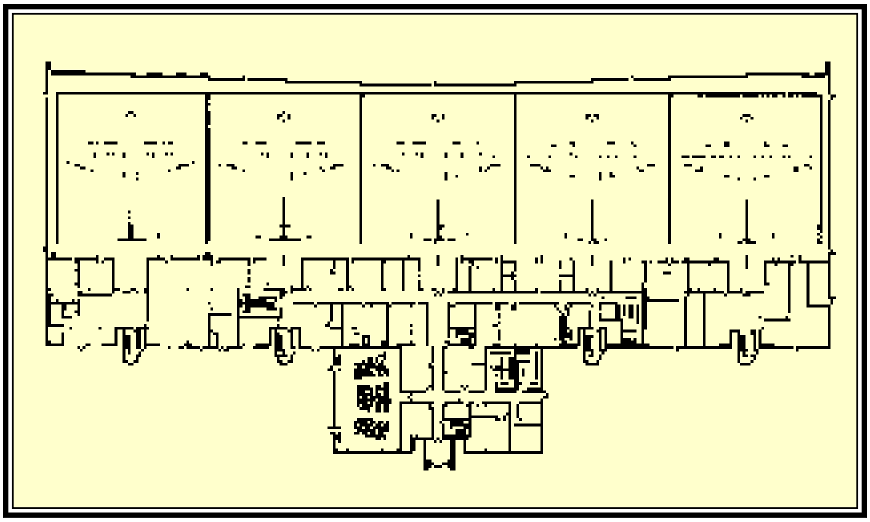
The five support towers are each located at 115' on center. The trusses are tied together with long-span joists. Horizontal trusses transfer the lateral loads to the back wall of the hangar and the rear wall of the building, both of which are a combination of braced walls and rigid frames. "The client didn't want braces in the offices and classroom spaces," James A. O'Kon, P.E., president of O'Kon & Company. "if you walk through the interior of the building, you don't see a single brace."

The support towers are a hybrid system consisting of W14 wide flange members for the bottom 55' and 20"x20" tubes for the upper portion. The towers are braced with 20" x 20" structural steel tube members with rigid connections. The rigid connections were designed to form a horizontal ductile frame, which provided lateral support for the tower, stays and cantilever truss system. Because of the possibility for cumulative deflection, all of the bolts were fully tensioned using load indicating washers.

In addition to the 600' x 135' roof structure, which consists of 94'-long LH joists from AISC-member Vulcraft, the tower frame system supports 110,000 sq. ft. of applied instructional building and aviation maintenance areas located on two structural levels adjacent to the hangar bay. The hanger structure is designed to be laterally expanded in the future.

Foundations for the structure consisted of 55'-deep reinforced auger cast pilings 14" in diameter. The loading reactions on the piling system reverse from a downward direction during gravity loading to uplift reactions of more than 1,300 kips when subjected to wind loadings. This cyclic reversal of large forces was a critical element in the design of the structural frame.

The 600' length of the building required two expansion joints, which were located adjacent to the second and fourth structural tower system. The expansion joint locations resulted in creating a building superstructure that was subdivided into three independent lateral force resisting systems. These systems had to resist transverse and longitudinal wind forces. The torsional forces created by longitudinal wind forces were resisted by a combination of the tower support systems and a line of steel bracing located in the rear wall of the hangar and the rear wall of the instructional building. The stayed trusses on the tower frame included horizontal bracing extending from the rear of the frame to the head truss at the hangar bay doors. The horizontal bracing transferred longitudinal loads from the side walls of the hangar to the rear lateral bracing system.



One of challenges on the project was to design a roof system that would not only resist gravity loads, but also the large horizontal forces and as much as 80 psf uplift forces generated by wind when the 600'-long-by-40'-high doors are open. According to design calculations, uplift forces in a storm could exceed 1,300 kips.

Designing the lateral force resisting stayed cantilever system was greatly facilitated by the three-dimensional computer model. The computer analysis was used to predict maximum deflection under gravity loading, volumetric changes and wind forces (up and down), as well as deflection to be used in cambering the structural steel.

The $22 million building utilized 1,600 tons of structural steel. General contractor on the project was Perry McCall, Jacksonville, and fabricator was AISC-member Qualico Steel. Steel erector was AISC-member Horizon Steel Erectors, West Columbia, SC. Project cost was $117/sq. ft.

The maximum vertical deflections are reflected in the mechanical connections at the top of the hangar bay door. The deflections are accommodated by