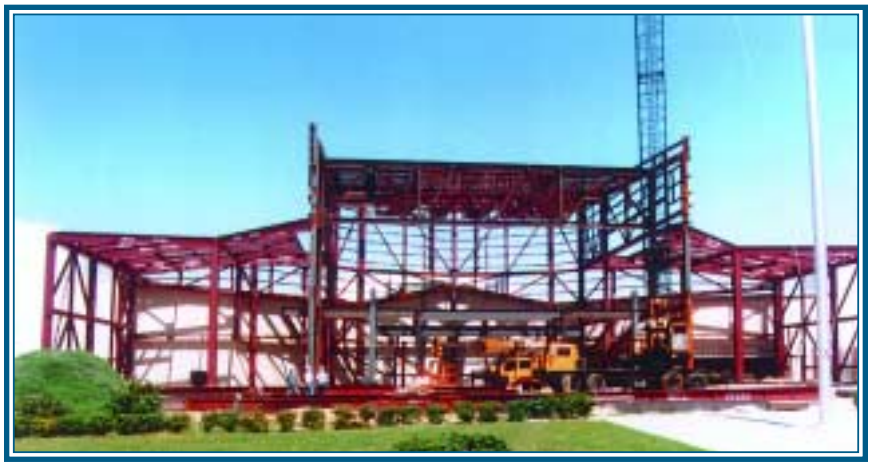
Top Gun

An addition to the National Museum of Naval Aviation will showcase the latest aircraft



By Steve Harwood, P.E.

A NEW ADDITION TO THE NATIONAL MUSEUM OF NAVAL AVIATION PROVIDES a main entrance to two 200-ft.-by-200-ft. by 50-ft. high column free exhibition halls. These exhibition halls are flanked by adjacent 42,500 square foot exhibit spaces plus a 100-ft.-by-100-ft. atrium building. Each of the buildings have been designed with integrated expansion capabilities by Paul K.Y. Chen, Architect and Harwood Associates, Structural Engineers.

The first wing or quadrant was completed in 1975. At that time, the museum's requirements for the building was to provide column free space for interior exhibition of historic Naval aircraft. Additionally, this structure was to be designed to suspend historical, decommissioned Naval aircraft. exposed web tapered steel members were used due to their economy and strength. Three main 200-ft.-long rigid bents, in each orthogonal direction intersect continuously to serve as the primary framing system. Secondary frames connect to the main rigid bents. Surrounding the main exhibit area, there are three 7,500-sq.-ft column-free mezzanine areas for smaller exhibits while at the same time providing a different view of the exhibits below in the main exhibit space. A central skylight located between such frames provides natural light and is the focal point of the major display.

This structural system performed extremely well because it offered highly economical space with total exhibition flexibility. The structural system was ana-

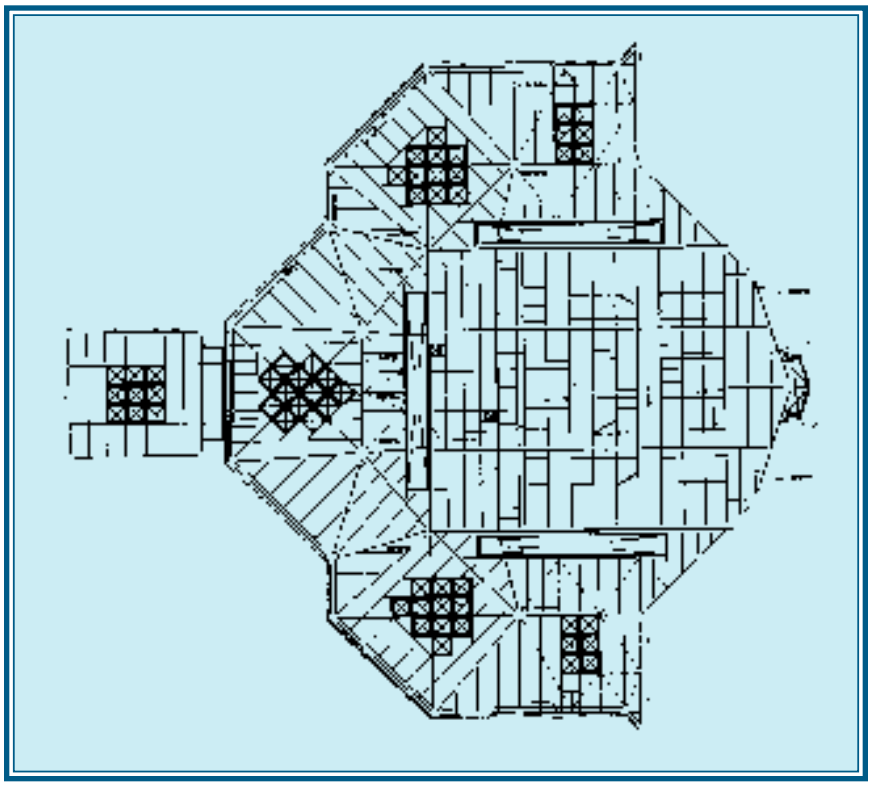
lyzed and designed as a rigid space frame.

The exposed steel frames provide lateral resistance and vertical load carrying capacity while adding a battle ship feel to the museum. These frames proved to be more economical than bolted or welded trusses. A 3-in. diameter tie rod is used underground near the top of the foundation to distribute its load from the rigid frame action. The entire structure is designed for 127 mile per hour wind load.

Complex Addition

Twelve years later the next quadrant was designed to mirror the original museum. However the height above ground increased by 12-ft. The increase in overall height was required to allow a scale model of a battleship tower to be installed. The model was constructed from ¼-in. plate. The web tapered framing system of the building which provided lateral stability was modified to incorporate all secondary frames. The ensuing three dimensional rigid space frame had bolted intersections of the web tapered frames. SAP90 was used to analyze three dimensional rigid structure. The basic web tapered member used varied from an 18-in.-by-½-in. web at the base to 6-ft.-10-in. at the haunch to 3-ft.-2-in. deep at the center of the 200-ft. span.

Along with this museum module an atrium building was added. This building's primary function was to house the original Blue Angel's aircraft in a diamond formation. The atrium building is approximately 100-ft.-by-100-ft. and 80-ft.-high with perimeter connecting mezzanines. The four side walls are braced tubular frames with large bays to allow aircraft that are on exhibit to be relocated. The atrium's columns in the corners are 24-in.-by-24-in. built-up tube sections. The balance of the columns are built-up 16-in.-by-24-in. sections. The service bays are 50-ft. wide to allow the aircraft to access the interior exhibition halls.



The square atrium building comprised of the four diagonally braced frames that were connected at the top via a steel two way space frame. This space frame functioned as horizontal diaphragm for lateral forces plus a support structure for the overhead 100-ft.-by-100-ft. skylight and the four suspended Blue Angel aircraft. The side wall frames with the roof space frame were analyzed together to ensure deformation compatibility using SAP90.

Attention Grabber

A keystone for this project is an exterior-exhibited F-14. The Museum Foundation requested the F-14 to be supported upon a single pylon with the center 15-ft. above grade with the aircraft on a 20 degree angle with respect to its transverse axis. The design criteria was 75 mph wind plus the natural frequency of the pylon was to be matched with that of the engineless jet. The design solution was to use a tapered steel triangular prism which varied from a 2-ft.-10-in. side at the top to a 5-ft. side at the base. The base of the pylon's steel plates were attached to a series of 24-in. grillage beams which in turn are anchored to a 20-ft.-by-20-ft.-by-4-ft.-thick foundation. In addition, chain tie-downs are used to restrain the F-14 at winds greater than 75 mph.

It has been reported to me by Grumman, the plane's manufacturer, that an F-14 takes off a fighter deck at 110 mph. The pylon (plus three additional chain ties which are used for torsional restraint) holds the F-14 stationary in hurricanes. SAP90 was used for the finite element analysis of the plate pylon and the frame grillage. SAFE was used for the foundation design.

Recently completed and ready for occupancy this May is the new 45,000 square foot main entrance and theater wing. This 200-ft.-by-180-ft. structure connects the recently constructed exhibition halls. The building

has fifteen sides (with no right angles) which encapsulates a 530 seat IMAX theater plus additional exhibition space. The roof of this structure has two levels, one at 40-ft. and the other at 70-ft. above grade. The structural system was analysed as a three dimentional braced frame using SAP90.

There is a bolted truss which spans 80-ft. at the interface of the low point of the high roof to the high point of the low roof. The truss is formed of W21x93 top and bottom chords with W8x40 diagonals and struts. From this truss mechanical floors, projection rooms and mezzanines are suspended. Beyond the high roofed theater there are only four interior columns.

Column Design

These columns are for gravity loads only. The perimeter walls are braced tubular frames. The top of these walls are connected to the low roof structure which is a horizontal diaphragm. The roof diagram spans about the five skylight clusters. The low framing also supports suspended aircraft such as helicopters and dirigibles. The high roof which is 86-ft.-by-112-ft. column-free space is above the theater and suspends catwalks, lighting, HVAC and audio components and a ceiling. At the high point columns are unbraced for a height of 70-ft.

Tube sections were used for these columns due to strength and economy in material. The fabrication of this exposed skeletal structure was accurate due to precision detailing. The local fabricator purchased prefabricated special size tube sections instead of fabricating in shop. This expedited part of the project. The project, due to its special shape and function required cooperation from both the erector and fabricator. The General Contractor Whitesall Green orchestrated the construction to meet the opening date deadline. Field welding of the connections was used due to the intricacy of the compound angle connections.

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