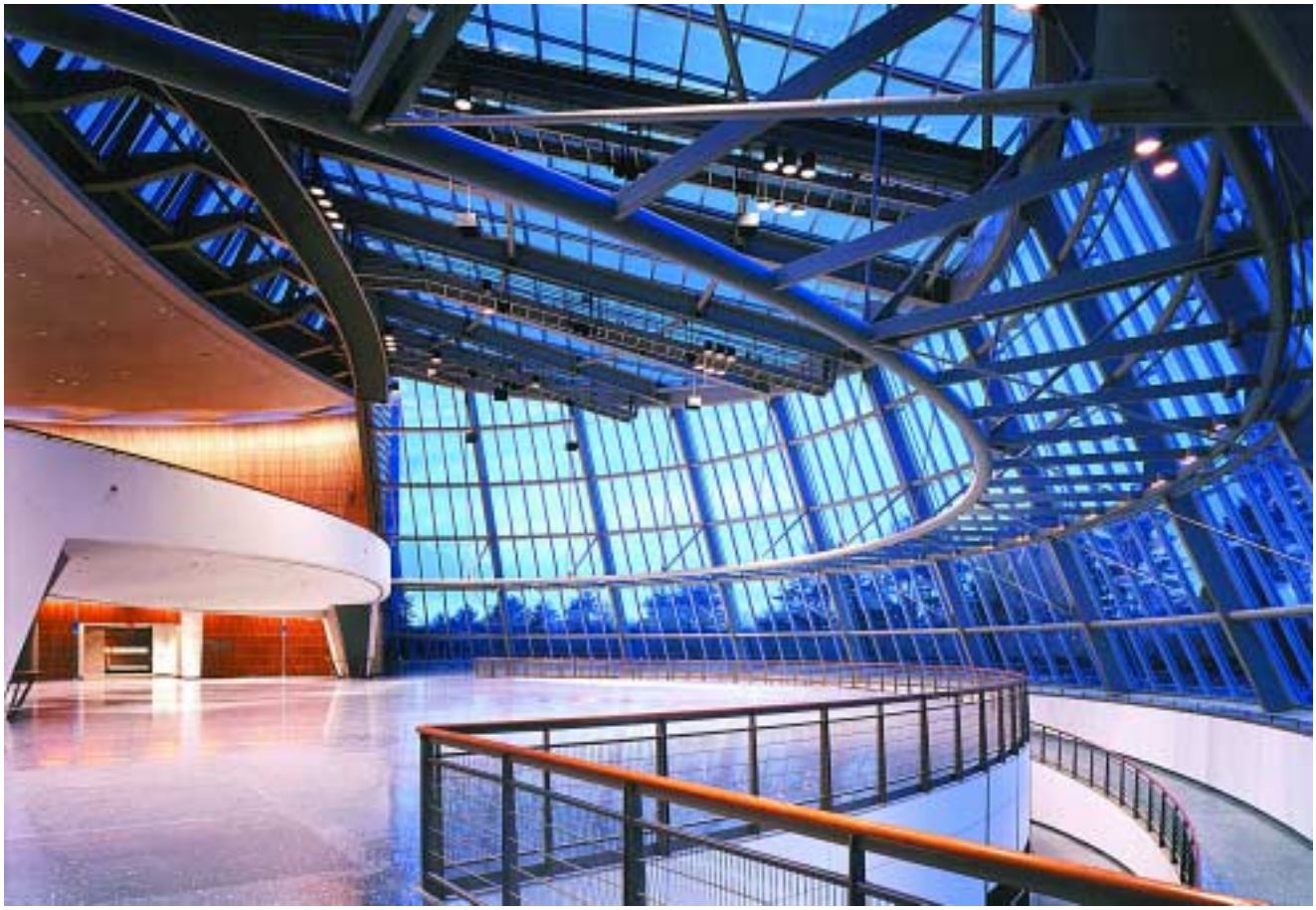

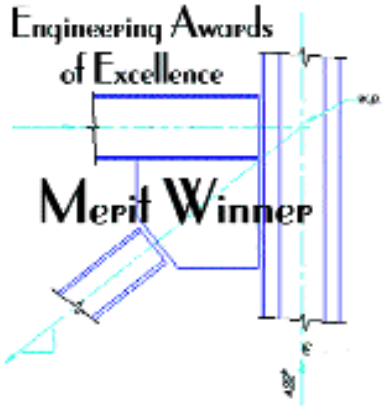

Mashantucket Pequot Museum

Ledyard, Connecticut

Ove Arup and Partners (Arup) was contracted in 1993 to provide structural engineering services for a new museum and research facility for the Mashantucket Pequot Nation. The new 308,000-sq. ft. facility rests on the tribal reservation in Ledyard, CT. The goal was to create a major resource to study and promote American Indian Heritage, scholarship, and cultural preservation and to relate the story of the Pequots through an innovative and forward looking design. Well-known museum architects, Polshek & Partners, NY, were chosen to lead the design.

The creation and construction of the museum resulted from a twenty-two year old dream and desire of a handful of tribal members to tell the story of the Pequots. The Pequots' desire for the building to merge with the natural form of the landscape governed the architectural form of the building.

Incorporating the latest in archival and exhibitory technology, the building developed into five distinct, yet interconnected, structures stretching over 800'. Each of the structures served a

different function within the center. The first four structures above are contiguous and separated by 8" wide seismic joints.

The 5-story "Bar" building, a linear structure, houses the administrative offices, research, archaeological preservation, laboratory facilities, and soon to be the largest Native American library in the country.

The two-story Museum Building, an organic form, accommodates the exhibits, including a re-creation of a 17th century Pequot village and two circular "War Theaters". The roof of the museum is a stepped terrace with differing landscapes progressing from east to west, with much of the interior space double height for exhibitions.

The Gathering Space building, a 170'-0" diameter x 60'-0" high partly glazed building, contains

the main entrance and ticketing, performance auditorium, dining, and catering facilities. The Gathering Space provides the point where visitors access all areas. A 75' high glass hall serves as the architectural focal point of the building and as the main entry, the form based on the strategically offset semi-circles of the 1630s Pequot fort at Mystic. The original fort is highly symbolic and central to Pequot history.

A 210' high observation tower functions to punctuate the overall building's architectural statement. The Tower is semi-enclosed by stone and contains only a stair, an elevator, and an enclosed observation deck at the top used for viewing the surrounding countryside and the reservation. The tower operates as the southeast visual anchor of the building. Its aspect ratio is 14:1.

The Central Utility Plant (CUP) Building, a remote one-story building built underground on three sides, contains chillers, boilers, generators and other MEP equipment. The CUP connects to the main building by a tunnel.

Design Challenges

The client had already retained the exhibit designers before the building form had been fully defined. They assisted the client in creating the different chronological exhibits that ranged from the ice age to the present day and graphically told the story of the Pequots.

The landscape architects were responsible for creating the different flora of the stepped terrace over the museum as well as the landscaping around the buildings.

A major challenge for the geotechnical engineers was providing an efficient drainage system for the ground surface water given the large expanse of the structures. Providing HVAC services to the remote ends of the building given the plant room locations within it was also a challenge for the MEP engineers.

Although Arup's responsibility was primarily to provide structural engineering services, the responsibility extended to provide a fire engineering study for the Gathering Space.

Jurors' Comments:
A complex mix of structural solutions to the architect's design. The use of fire engineering to preserve the use of exposed structural steel in the gathering space while at the same time saving the owner $750,000 is worthy of note. A project of obvious architectural significance supported by engineering ingenuity.

Structural Design

Expansion joints were provided at pre-determined locations to separate the "independent" buildings, although due to its configuration, part of the Museum structure is tied to the Gathering Space structure.

The Bar Building, a simple steel framed building, tied to the retaining walls for the two lower floors and a standard beam/column construction above the third floor. Moment frames in both the east-west and north-south directions provided lateral stability for the building. A full 3-D model was developed and analyzed for lateral loads (including torsional seismic forces) and resulted in the provision of a maximum expansion joint of 8". The provision of a heavily loaded library on the fourth floor contributed significantly to the expansion joint width especially under seismic loading.

The western half of the Museum, a 2-story structure with two 2-story high 60'-0" diameter circular concrete walls, forms the War Theaters and a single story wall on the west side. Steel framing on top and between these structures support the roof and floor structures. The west side wall and the 2-story high concrete walls of the War Theaters provide the resistance for the lateral forces for this building. The lateral load resisting system was complicated by the stepped nature of the Museum roof slab. Because of this, seismic loads were carefully analyzed in a 3-D model that included the round concrete structures required to provide stability, finding that the asymmetrical location but substantive circular forms of the War Theaters efficiently resisted the high roof loads comprised of assembly, soil, and snow loads.

Combining simple conical and cylindrical shapes, truncating them by angles off the horizontal and then offsetting the two halves of the resulting circular base developed the geometry of the Gathering Space. The result is a 192' center span 3-dimensional truss stabilized by the roof beams it supports. A combination of moment frames and braced frames for the southern half of the space and moment frames and the concrete walls of the Museum to the north and east provided the stability for the Gathering Space glass structure.

A full 3-D model was developed for the analysis of the Gathering Space structure because of its extremely complicated arrangement.

Due to the size and unique shapes of the Gathering Space and Tower, CPP in Boulder Colorado arranged a wind tunnel. The results were used in the structural analysis to alter the assumed loads derived from the Code. Qualitative studies of snow deposition were used to supplement minimal loads calculated per the Code, particularly helpful in identifying areas subject to additional snow-drifts.

To achieve the architectural expression of exposed steel in the Gathering Space, Arup Fire conducted a fire study for submission to Code officials. The results of the study indicated that the required two-hour rating was achieved given the nature of the building and any conceivable fire loads. The results were accepted and the result was elimination of fireproofing of the steel and consequent savings of $750,000 for the Owner.

The complex geometry and large forces from rigidly connected framing members particularly challenged the design of the architecturally exposed roof connections.

In order to provide the long clear spans in the Gathering Space and lateral stability for the glass roof, the roof-framing members typically carried both axial forces and bending moments in both principal axes. At the end of the bifurcated shaped arch, as many as nine members converged from different angles into one rigidly connected joint. The amount of weld metal used for each of these "bell" connections estimated by the steel fabricator to be over 1000 lbs.

Braced frames in the east-west and northwest-southeast directions and moment frames in the north-south direction provide the lateral resisting system for the Tower. Here also a 3-D model for the analysis was created because of the extreme aspect ratio of 14:1 of the structure. Surprisingly, because of the braced lateral support system used, the Tower was relatively stiff, with deflections well within acceptable limits. The wind tunnel investigated a separate aeroelastic model of the Tower. The results indicated uncomfortable accelerations at the Observation Deck in wind speeds higher than about 20 mph. The client was advised and decided to limit access to the Tower when wind speeds exceed this amount in future.

Due to the complex geometry, the usual tolerance requirements specified by the AISC Code of Standard Practice were not applicable. As a compromise for buildability, we reanalyzed the Gathering Space structure and determined that tolerances 10% below AISC standards were structurally acceptable. This meant, however, that the design team had to examine each joint to determine the maximum allowable tolerance in terms of the structural forces and architectural requirements. The erection of the Gathering Space was monitored vigorously to ensure the erected structure would meet the project tolerance requirements. To monitor progress of the erection and surveying of the Gathering Space structure, the Construction Manager built a 1/8" scale model and each member of the model highlighted as it was erected in the field. We were intimately involved in the rigorous survey regime that determined locations before and after welding for each of more than 500 points. Even though tolerances were exceeded at several locations during construction, the design team backchecked the design with the given information to verify that the roof structure was not overstressed.

In one of the most impressive results, surveys before and after removal of the falsework for the 192' roof arch determined that the unshored structure was within $^{1}/_{16}$" of calculated deflections.

The museum was officially opened on August 10, 1998 in a ceremony that included traditional Native American rituals and congratulatory messages from the President of the United States and other tribal nations.

Arup was part of the design team led by Polshek and Partners that included Exhibit designers, Design Division, Inc., MEP and fire protection engineers Altieri, Sebor Weiber, Landscape architects Office of Dan Kiley, and other consultants.

Mashantucket Pequot Museum, Ledyard, CT

Owner: Mashantucket Pequot Museum

Architect: Polshek & Partners, New York, NY

Structural Engineer: OVE Arup & Partners, New York, NY

Fabricator: Cives Steel Company, Roswell, GA *(AISC member)*

Erector: Berlin Steel, Berlin, CT *(AISC member)*

Detailer: Computer Detailing, Inc., Salt Lake City, UT *(NISD member)*

General Contractor: Pavarini Construction Co., Ft. Lauderdale, FL