RAISING the ROOF

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A steel roof-raising renovation saved time and money for the Allen County War Memorial Coliseum in Fort Wayne, IN.

Sixteen 223-ton capacity strand jacks that were used to raise the roof. The strands were threaded into the jacks prior to installation onto the temporary jacking platforms shown.

Engineers working to expand the Allen County War Memorial Coliseum in Fort Wayne, IN were faced with a complex challenge: to design a new roof structure that would allow for the expansion of the existing arena from 10,000 seats to 12,000 seats with minimum interruption to the facility's extensive event bookings. Initial project exploration revealed that constructing a new roof could not meet schedule and budget requirements for the project, so designers chose to reuse the existing roof by elevating it to create an expanded space.

EXISTING STRUCTURE

When it was first built in 1952, the 224' building was the longest clear-span structure in the United States. The arena mainly consisted of eight identical steel plate girder frames spaced along seven equal bays of 27'-

View of the raised coliseum roof structure, facing north. The skeletal end-wall framing steel and siding liner panel were installed prior to the lift to expedite a watertight building.

0". These frames were of the high-profile type with a 3½:12 roof slope. At both north and south ends of the arena, the structure stepped down by decreasing both span length and height of the framing.

The steel plate girder frames consisted of 5/8" web plates, 4'-7" deep at the vertical portions of the frame, and 6'-0" deep at the inclined roof portion of the frame. Flange plates were 18" wide, and ranged from 1½" to 2½" in thickness. The pitched roof followed a slope of 3½" in 12". The frames had a span of 224'-0" center to center. At the low ends, the frames were 54'-10" tall. The ridge was located at 88'-3" above the arena level.

Half-inch stiffener plates reduced the web plate's tendency to buckle. Their locations coincided with the locations of 12"-deep purlins, that were spaced approximately 6'-0" on centers, supporting 4"-thick lightweight concrete panels. These panels were precast and reinforced only by two small-diameter steel bars. Two tension rods of 2" diameter, used to tighten the anchorages and plumb the frames, resisted the horizontal thrust of about 110,000 lb.

Engineers were able to extract a great deal of useful information from the original design documents. From the location of field splices it could be deduced how the frames had been erected, which helped to understand the internal stresses of the frames.

RENOVATION

In the mid-1990s the Allen County War Memorial Renovation concept was developed. Several different designs were explored to accommodate additional seating requirements (see sidebar, p. 39, "The Decision to Raise"). CBN Steel provided estimates of construction costs for various designs. Extensive consideration was given to constructing a new truss system over the top of the existing structure. However, this plan would have been cost and schedule prohibitive. The challenge of working over an elevated floor slab added to the proposal's complexity. Finally, the idea of reusing the existing roof structure at a higher elevation was developed. It provided a cost-effective means to create additional seating and allowed the project to be constructed in two phases, without interruption to the arena operations. The existing structure would be reinforced to allow the roof to be raised.

SCHEDULE DIVIDE

Once Allen County accepted the plan, architect MSKTD of Fort Wayne, IN created architectural and structural drawings. In February 2001, general contractor Hagerman Construction, of Fort Wayne, IN awarded CBN Steel the

View of coliseum at the new raised height of 41'-10" above the previous position. The final elevation of the peak is roughly 120' above grade.

roof-raising portion of the structural steel package. Schedule requirements were very stringent in order to complete such a major renovation of the structure with minimal effect on its operations. Hockey season was scheduled for October through June both in 2001 and 2002. All construction was planned to accommodate this schedule and the other events hosted throughout the year. CBN Steel's challenge was to divide the scope of work between the two windows of opportunity. In summer 2001, the new hanger and catwalk systems required for rigging and lighting were erected; and in 2002 the roof structure was converted into a tied-arch system in preparation for lifting.

ERECTION

Erecting from the ice arena floor was a challenge for CBN, but engineering time and dollars had to be spent up front to assure the safe and successful erection of the required reinforcing from inside of the arena. Because the ice arena floor was built over a basement, special care was taken to prevent excessive deflections that could have damaged the embedded coolant lines.

The summer of 2001 was spent erecting the steel forming a horizontal grid system to support live loads from sound and light systems for shows. Gravity loads from this grid are supported by a series of diagonal HSS members, placed in the plane of the frames. All eight frames were fitted with attachments at their ends suitable to transmit the lifting forces of the existing roof's dead load to the lifting devices attached to the ends of the concrete frames. CBN also prepared most of the girders for the installation of the tension ties, two 1¾" 150 ksi rods that would support the roof after cutting it free. These tension ties were required to resist the outward thrust of the ends of the girders: once the girders were cut free from the columns, the release of internal stresses would have caused the ends of the girders to move outward about 2'.

During the summer of 2002, the long-span girders were converted to tied arches by installing the tension rods at each plate girder just below the "elbow" of the existing steel girder frames. Each tied arch was gradually pre-tensioned to 240 kips as the roof was cut free of the abandoned column stubs below. Throughout the cutting procedure the movement of the girder was monitored with slotted girder web-control plates. These connections were sized to accommodate the dead load of the structure, and to allow for horizontal forces from girder movement.

The cutting process was slow at first, since each cut was closely monitored to ensure that the structure behaved as modeled. After the successful release of the first two trusses, the building was performing as predicted, which allowed the cutting process to speed up. As the building was cut free, CBN Steel simultaneously installed a series of 16-strand jacks to hoist the roof from above. Each jack had a capacity of over 100 tons, and was composed of a series of seven lifting cables.

BIG LIFT

With the rods tensioned and the girders cut free from their columns, raising the roof was equivalent to raising a 2.3-million-lb. loaded spring. On Aug. 2, 2002 the entire 1,200-ton structure was lifted 41'-10" higher to its new resting position, connected to the 16 new concrete cantilevers that reach out and grab the roof. The lift took just under five hours to complete and it went up without a hitch. The ability to reinforce and reutilize the existing steel structure resulted in a major cost saving when compared with the possible construction of an entire new roof system. The owner remained in operation during the renovation, resulting in $3 million of revenue that otherwise would have been lost if the facility had been closed throughout construction. ★

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FABRICATOR
Almet, Inc., New Haven, IN
(AISC member)

DETAILER
CBN Steel Construction, Inc.
(NEA member, AISC member)

GENERAL CONTRACTOR
Hagerman Construction Corporation, Fort Wayne, IN

The Decision to Raise

Project structural engineer Helmut Cerovsek, P.E. of HNTB elaborates on why the coliseum roof was raised and not razed.

When we were first consulted for structural input, the architectural concept was to span the newly created space by using long-span roof trusses with level bottom chords and slightly pitched top chords. These trusses were to be erected over the existing roof structure. Demolition would commence after the new roof had been completed. This scheme, although column free, created two distinct problem areas:

- It was not immediately evident how one would erect trusses spanning some 350'-0" over the existing structure, with restricted access due to the older buildings surrounding the arena.
- It became clear that this scheme would create an enormous volume of space with very tall and imposing end walls. Budgetary restraints also could complicate this plan.

After considering alternatives, we proposed a new plan, later nicknamed the "W-Scheme." This scheme left about two-thirds of the existing roof structure in place, and only opened up at the east and west ends by adding "wings" to the remaining structure. After completion of the addition, the roof cross section would be in the shape of a "W." Prestressing cables at the bottom of the steel plate girder would have been required to balance external loading and for deflection control. Reinforced concrete frames and stair towers could be used to overcome the significant horizontal thrusts.

One prospective construction manager offered to improve on the "W-Scheme" by using newly constructed arch trusses to improve the clear view across the arena. With the arch-truss scheme, all of the existing roof would have been demolished. After careful study of this alternative, we came to the conclusion that the arch-truss concept could not be built economically and within the allowed construction schedule.

Later, with the final construction manager chosen, the use of "King Trusses" and super long-span, open-web steel joists was proposed to significantly reduce costs. However, the challenges of transmitting the very large roof loads through the existing structure, coupled with program issues (the king trusses would obstruct some views, internal roof drains were prohibited, etc.) proved too much for this scheme.

To reduce the construction costs, it was clear that saving large portions of the existing roof structure would make a significant difference—but the existing roof simply was too low. The construction manager proposed the possibility of raising the existing roof. In order to save on the large costs associated with the new end walls, it was imperative to keep the building profile as low as possible, without compromising the internal clear view requirements. An early scheme raised only six of the eight frames, with two 27'-0" end bays dismantled and re-built, but the tight construction schedule would still be hard to meet. As a result, the project moved forward with the only option that could meet the budget, time, and structural requirements: raising the existing roof in its entirety.