CONOIDAL FACADE CASTS LIGHT ON COURTHOUSE

Part of the United States Courthouse and Harborpark includes a transparent wall with exposed steel

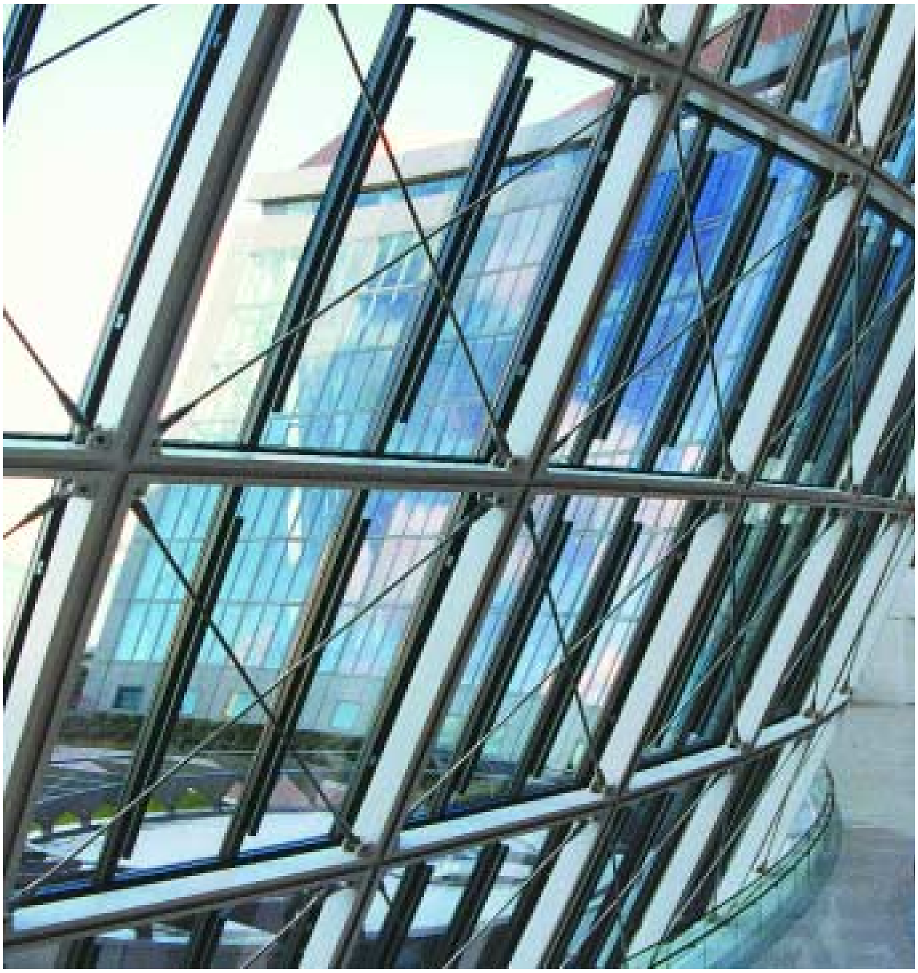
By D. Fraser Sinclair, P.E.

ONE OF THE MOST IMPORTANT ARCHITECTURAL FEATURES OF THE NEW U.S. COURTHOUSE AND HARBORPARK in Boston is the sleek, curved facade that faces the city across an inlet of Boston harbor. In contrast to the brick used on the rest of the building, this transparent glass surface is a gesture to public access and the openness of the judicial system.

During the design of the building, special attention was given to the detailing and constructibility of this wall. Glazing systems were deemed workable even with the curious "conoidal" geometry. The sticking point was coming up with a structural design, which could do justice to the wall's lofty intent. Conventional approaches using vertical beams or pipe-trusses to span the 90' height presented a very cluttered interior.

The final design shows not only how the structural was reduced to a mere 10" thickness over the entire 90'-by-380' expanse of glass, but also how construction issues played an equally vital role in the design process.

Since there was no precedent for such a structure, the GSA insisted that the contract drawings include detailed instructions for at least one method of construction. Although the proposed method, and the design itself, were under the constant assault of compromising alternates (inherent in any publicly bid job), in the end the wall was built exactly as designed.



The most important innovation of the design was eliminating the necessity for any prestressing after erection. Until now, a structure of this type was deemed extremely risky because of the complex shoring and fieldwork required. The unique panelized approach allowed for all complex operations to be performed off-site, provided a self-aligning system of erection, and opened up the bidding to less specialized contractors. The panelized approach, however, had a potential drawback. The wall needed to be a continuous surface, not visually broken up into a patchwork of panels. By detailing the interior surface of the structure with grooves in the horizontal and vertical members, the panels were made effectively invisible. The grooves not only accentuate the notion of a surface but also provide a means to disguise the inevitable misalignments that occur during construction.

Instead of the usual round-edged tubular members, the design features standard channel shapes which yield a crisp new look in long span exposed steel. Prestressed stainless steel rods were also used, complete with yacht racing fittings at the connections.

DESCRIPTION

The structure weighs 12.5 lbs./sq. ft. and the entire conoid structure is made up of 35 panels, fabricated and prestressed off-site and welded together in the field. Field joints are detailed so that the panelized construction method is not visually apparent in the finished continuous surface.

Cables were ruled out in favor of stainless steel rods, using technology that was developed for sailboat riggings. Instead of tensioning the entire surface from top to bottom and side to side, the design relies on an intermittent tension field wherein all the rods are under tension but the prestress force at the center of every joint in the frame is zero. This means there is no tendency for the panel to buckle during and after prestressing and prior to erection.

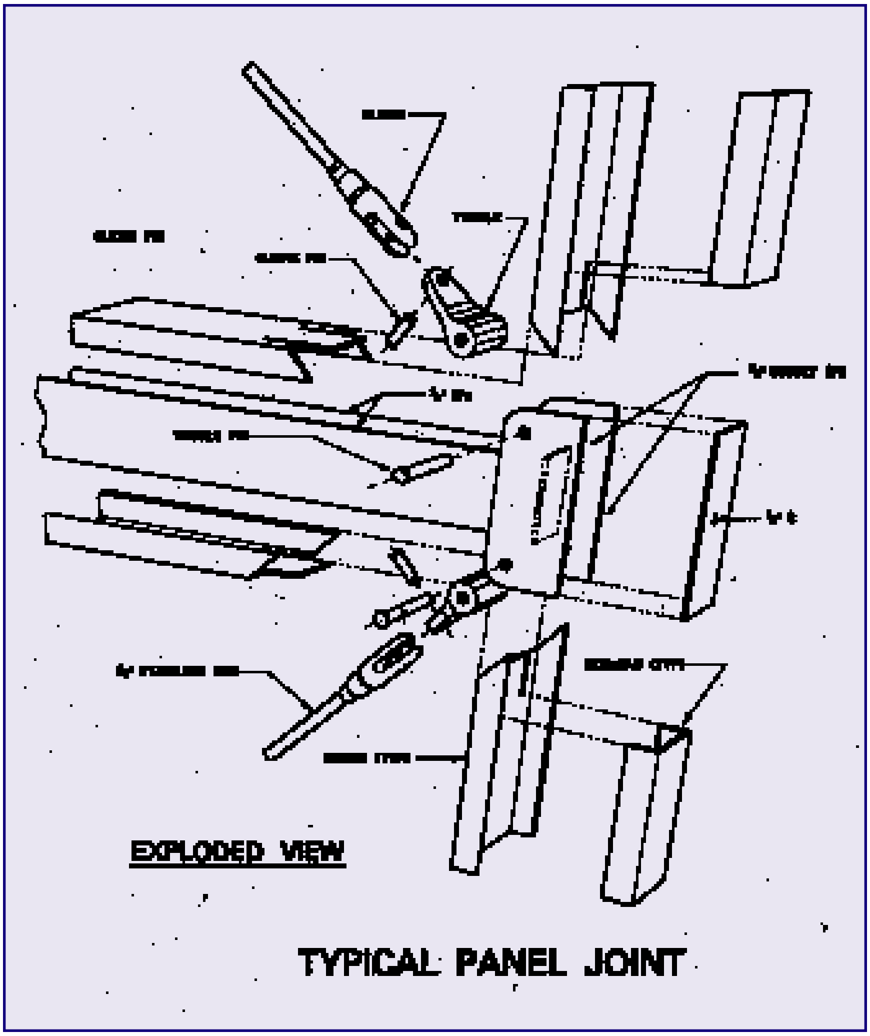
Support of the framework is provided at the four edges: bottom supports are welded fast to the second floor framing and take the full weight of the framing and glass in addition to the in-plane membrane forces and out-of-plane shears. Side supports are provided by tube struts that are attached to the end truss chords and anchored to the building. These supports allow movement of the conoid frame perpendicular to the end walls. Top supports are provided by slide bearings, which allow movement in the plane of the conoid surface but restrain movement perpendicular to the surface.

Once the structure is welded together it forms a shell, achieving stiffness and strength from its overall curved shape-—he principal forces are in plane rather than out-of-plane. The field of stainless steel rods achieves high in-plane shear stiffness. Prestressing the rods allows all rods to contribute to the stiffness by preventing them from buckling. Rods are tensioned so that the most severe loading will not force any rod into compression. Boundary trusses at the two sides provide additional stiffness.

GEOMETRY

Straight lines emanate from an apex point 643' below ground level and generate the conoid surface. All horizontal sections through the surface are circular.

Since all "vertical" members, if extended, pass through the conoid apex it follows that the panels are planar and all front



and back surfaces in a given panel are in the same or parallel planes. This greatly simplifies the fabrication.

The structural frame is offset from the curtainwall by a fixed horizontal distance and therefore describes a conoid, which is parallel to the curtainwall. However, because of the varying angles of the panels to the horizontal, the perpendicular distance from the centerline of the structure to the curtainwall surface varies by 3/8” between the center panel and the end truss panel. This is accounted for in the design of the curtainwall attachment brackets.

STRUCTURAL NOTES

Wind tunnel studies generated patterns of wind loads used for the analysis. Some of these had inward pressures as well as outward suctions acting concurrently on different portions of the frame. The natural period of the framework is well below that of the wind gust regime.

Building movement causes some of the most severe loadings. Since the slide bearings at the top edge restrain radial movement, radial building drift between the second and ninth floors generates large forces in the conoid frame.

DESIGN ISSUES

One of the early design problems to solve was how to slice the vertical members in two, allowing a panelized approach to the design. With only half of the final cross-section in its vertical members, a panel needs to be strong enough to take the prestress load prior to erection. This was accomplished by building up a box section from two standard channel shapes with enough weak-axis stiffness to prevent buckling during prestressing. In the final condition after welding to the adjacement panel, these combined verticals pick up extra strength (due to the increased moment of inertia) to resist the wind and earthquake loads in the permanent structure.

Another design problem, closely linked to the architecture, was what to do at the intersections of the horizontals and verticals. Because of the five-degree angle change between panels and the fact that there is a slight step in the alignment of horizontals in adjacent panels, this joint was a daunting design problem. In the end, essentially eliminating steel at this location yielding continuous horizontal and vertical slots at the member centerlines solved the problem. To do this, the membrane forces were transferred to a "back plane" in line with the gusset plates and the 6" channels.

The base support condition was encumbered by an air plenum that was required for the entire length of the conoid wall. In order to channel the high in-plane forces from the conoid structure into the second floor slab it was necessary to bridge the gap under the plenum by means of a short depressed slab.

The stainless rods (1.25" diameter) are "cold-headed"—the ends are cold formed into a flared bell shape designed to bear on threaded seats in the clevis fittings. This type of end connection can develop the yield strength of the rod. The rods are offset ¾" from center depth so they do not touch where they cross.

PRESTRESSING

Two methods were used for prestressing 215 rods to 50 kips and 16 rods to 90 kips:

In the original specified method, hydraulic jacks pull the two clevis supports for a rod toward each other. When this is done the rod becomes loose but its opposing rod, which it crosses, picks up load and maintains equilibrium with the jacks. The threaded seats on the loose rod are then tightened and the jacks are released and moved to the opposing rod.

During construction, another method was suggested to the contractor to alleviate excessive build up of jacking loads for the rods that had to be stressed to 90 kips. This method involved machining a wedge to grip the actual rod and was in fact preferred by the contractor even for the 50 kip rods.

FABRICATION

AISC-member M&J Materials of Trussville, AL participated in the project as the steel fabricator and detailer. Since the fieldwork had been reduced to merely welding the panels together, the fabrication of the panels themselves was not on the critical path of the total building construction. This was an opportunity to create an intricate panel design, which would take advantage of advances in fabricating techniques.

The specified tolerance for the total panel height (90') was +/- 1/8" to ensure fit up in the field. Although this seems almost impossible to achieve, a key feature of the design enabled fine-tuning the panel alignment during prestressing. The fittings designed for the tension rods provide adjustment via a threaded seat in the clevis.

ERECTION

Temporary strongback trusses were included in the contract drawings because the panels have almost no stiffness by themselves in the out-of-plane direction. These strongbacks force the panels into a plane while they are hoisted into position and keep them aligned while they are welded to the adjacent panels. Alignment of the top of the panels during erection was accomplished with a plumb bob. Advanced Structures, Inc., served as an engineering subcontractor overseeing erection.

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