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PDX

Roadway Canopy and Pedestrian Bridges

Portland, Oregon

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The PDX Roadway Canopy and Pedestrian Bridges provided the final touch on an ambitious $150 million construction program to improve public access to the Portland International Airport. At less than 12 miles from the city center, the airport literally serves as the front door to the Rose City for over 14 million passengers annually. Today, the Canopy forms the ceiling of a grand new entry to the city of Portland.

Since construction of its first parking garage in 1988, the airport has experienced unprecedented growth with rates approaching 15% annually. This increase in use overwhelmed the existing infrastructure that serves the terminal, causing frequent backups on the roadway and closures to the parking garage. The Port of Portland in response to this phenomenal growth launched the Terminal Access Program (TAP) in 1994. The program consisted of several projects, including roadway widening, roadway realignments, terminal expansion, garage expansion, expansion of curb-side drop-off and pick-up zones, expansion of rental car facilities and finally the Canopy and Pedestrian Bridges, which tie all the other program elements together.

With parallel runways at each end of the terminal, there was no opportunity to extend the parking, road system and curb space linearly as is typically done at most airport expansions. The only economical option was to expand the parking vertically and create a series of adjacent parallel road systems on two levels. The Canopy and Pedestrian Bridges were in many ways the keystone of the overall program, which allows each of the other elements to function effectively.

The Canopy protects all of the road systems (drop-off, pick-up, parking shuttles, taxis, buses and commercial vehicles) as well as the Pedestrian Bridges from Portland's persistent rainy weather. With complete coverage by the Canopy, all of the roadway lanes can be used for pick-up or drop-off at peak times. The Pedestrian Bridges improve the roadway capacity in multiple ways. By creating direct protected access from the parking structure to the ticket lobby, many passengers now choose to park rather than use the terminal roadway at all. In addition, passengers no longer cross through vehicular traffic, which enables the roadway to operate more efficiently. The suspended Pedestrian Bridges also free the roadways of obstructing columns.

The Canopy extends from the west elevation of the garage to the east elevation of the terminal, covering a total area of approximately 120,000 sq. ft.

Ten triangular steel trusses, each 15′ deep and 12.5′ wide, span 180′ between columns at the garage and terminal structures. Trusses are spaced 55′ on center along the length of the roadway providing weather protection along more than 500′ of roadway. Each Canopy truss is constructed from three 16″ diameter parallel pipe chords bent in an arch shape. Truss web members, including verticals, diagonals and horizontals are constructed from 5″, 6″ and 8″ diameter pipes connecting at the chords with traditional, mitered, pipe-to-pipe T, K and Y joints. Specially designed open-web joists with WT chords and double-angle web members span 42.5′ between the triangular trusses as in-fill framing to support the glass skylight covering. Steel details were specifically tailored to support and minimize the cost of the skylight system, which includes over 2,800 individual panes of glass.

A pair of steel framed pedestrian bridges suspended from the Canopy trusses provides access between the terminal and parking garage for passengers. The Pedestrian Bridges span the expanded roadway from the fourth level of the garage to new vertical circulation cores at the terminal. Because vertical circulation cores at the garage and terminal do not align, the Pedestrian Bridges are constructed in an 'S' curve to deliver pedestrians from core to core. Bridges are framed with conventional slabs on metal decks spanning between composite, wide-flange joists supported by 3′ deep 'S' curved plate girders. The plate girders are suspended from the Canopy trusses with pairs of 1 3/8″ diameter, 150 KSI, Dywidag threaded steel tension bars in a splayed fan configuration located at strategic points along the length of the bridge.

Design loads for the Canopy and Pedestrian Bridges were based on Uniform Building Code (UBC) criteria. Because of the unique air-foil shape of the Canopy, wind tunnel studies were conducted to determine extreme wind loading conditions. Results of those studies indicated peak wind pressures well in excess of basic UBC requirements with wind loads as high as 80 psf at the leading and trailing edges of the structure. Other design considerations included Canopy snow loads, pedestrian live loads, thermal expansion and contraction loads and seismic loads. Because Portland is located in UBC Seismic Zone 3, site-specific investigations were conducted to determine appropriate seismic ground motions. Dynamic response spectrum analyses of the independent terminal and garage structures as well as Canopy and Pedestrian Bridge structures were conducted to determine each element's response to specific ground motions. Analyses of the Canopy and Pedestrian Bridges utilized three-dimensional computer modeling, requiring as many as 18 loading combinations to insure all conceivable loading conditions were accounted for in design of the structures. Design of the steel elements was based on provisions of the AISC Manual of Steel Construction for Allowable Stress Design (ASD), the AISC Manual of Steel Construction for Load and Resistance Factor Design (LRFD), and AISC Seismic Provisions for Structural Steel Buildings. The AISC Hollow Structural Sections Connections Manual was used extensively for design of the Canopy truss connections.

Because the Canopy and Pedestrian Bridges span between two independent structures, the design and detailing needed to allow the terminal and garage structures to move independently in a seismic event. To allow independent movement between the structures, the Canopy and bridges are anchored to the garage and allowed to slide on teflon bearing pads at the terminal supports. These slip connections proved challenging when designing the Pedestrian Bridge suspension rods. Because the Canopy trusses form an arched shape with the terminal end free to move, the arch tends to flatten and slide towards the terminal as it is loaded. As the Canopy trusses deflect and slide, loads in the Pedestrian Bridge suspension rods vary greatly due to their splayed fan configuration. In extreme loading conditions, some suspension rods would become slack and sag. To prevent this, pre-compressed coil springs were incorporated in the rod suspension system to maintain tension in the rods under all loading conditions.

Fabrication and erection of the Canopy and Pedestrian Bridges also proved challenging, since the airport, including roadway access, needed to remain operational during construction. A plan was developed with the Port and general contractor to temporarily relocate all public access to the lower roadway, leaving the upper roadway to serve as a protecting cover for the public below. Many other safety measures were included in the erection activities, such as debris netting, barricades and barriers and coordination with airport operation managers to insure public safety during critical activities. Fabrication of the Canopy trusses and Pedestrian Bridge steel was completed by an AISC Cbd Certified shop approximately 25 miles away from the airport and shipped to the site on flatbed trucks. Because each Canopy truss is 15′ deep, 12.5′ wide, and 220′ long, it was necessary to ship each truss in four individual sections. Before shipping, each truss section was fit-up in the shop to insure proper fit-up in the field. With restricted erection space and crane size limited by loading capacity of the existing roadway structure, it was necessary to erect each truss segment individually, temporarily supported by specially designed mobile shoring towers. After field connections were made for each truss segment, the shoring towers were lowered and rolled down the roadway in a leap-frog manner for erection of each successive Canopy truss. Bridge erection directly followed truss erection, allowing initial installation of the suspension rods from the completed trusses above. Bridge framing was initially erected on temporary shoring platforms to limit Canopy and Pedestrian Bridge deflection during erection and placement of Canopy skylight elements. Once placement of the concrete bridge deck was complete and Canopy skylight elements were in place, suspension rods were tensioned to finally lift and level the Pedestrian

Bridges from their temporary shoring. Erection of over 800 tons of Canopy and Pedestrian Bridge steel was completed in less that four months under very restrictive conditions.

Completion of the PDX Canopy and Pedestrian Bridges culminated with reopening of the upper roadway to public traffic on May 25, 2000. Thanks to the efforts of all involved, the project was completed under budget, ahead of schedule and without injury. As the final touch to the Port of Portland's Terminal Access Program, the PDX Canopy and Pedestrian Bridges not only provide a lasting first impression to Portland area visitors, but also serve as the keystone to the entire Terminal Access Program, allowing each element of the program to function most effectively.

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