Skybridge at Lincoln Square

With the completion of Phase 1 of the new Lincoln Square Mixed-Use Facility in downtown Bellevue, Washington, the owner, Kemper Development Co., requested permission from the city to install the first elevated pedestrian bridge in the downtown core area. Located at one of the busiest intersections in the city, the new steel-framed and cable-stayed structure spans 107 feet between the new retail, condo and hotel facility and the existing 35 acre shopping center at Bellevue Square.

By Dennis Baerwald, P.E., S.E., Narong Trongtham, P.E., S.E., and Darren Johnston, P.E.

The new covered bridge provides easy and safe access between the two major retail and parking areas. Arrival of pedestrians at the Lincoln Square side also coincides with the center's front door, adjacent to its 82-foot tall atrium and 60-foot high water feature. In plan view, the 11-foot wide, trapezoidal shaped bridge is skewed across the 107-foot span with a vertical curvature on a 1600-foot radius.

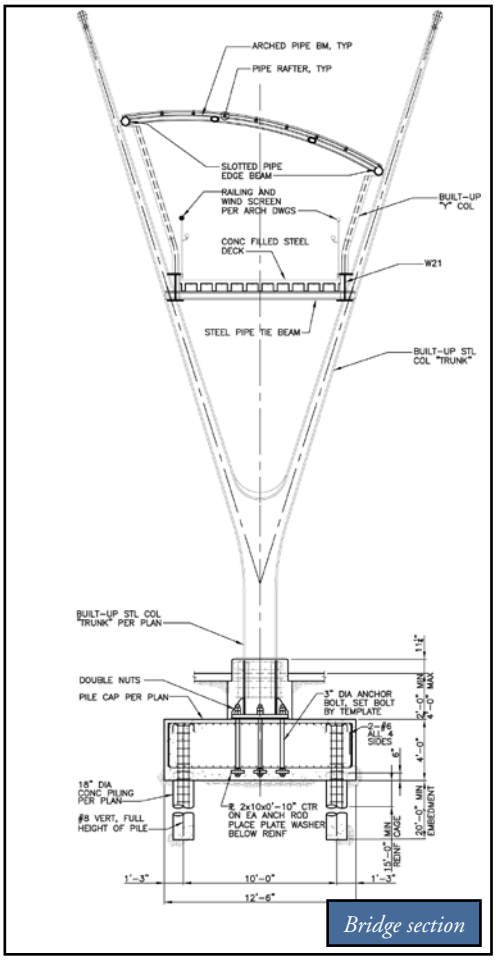
Because of the bridge's high visibility, the owner specifically requested that the design team provide a design that was thoroughly modern, transparent and comfortable to its users, without vibration or movement most common to cable-stayed structures. In addition, the design had to address the extremely busy, 5-lane arterial below, the existing occupied buildings at each bridge end, and the associated construction challenges.

The Sclater Partners architectural design team, led by Michael Chaplin and designer Rick Deno, worked closely with ABKJ structural engineers as they developed a lightweight and open cable-stayed bridge, suspended by two 4-pronged column trunks with extended masts to support the splayed bridge cables. The "Y"-shaped curved side columns, spaced at 14 feet o.c. along the bridge sides, mirror the support "trunks" design and provide unusual and interesting "tree" supports to the upper roof structure. The entire roof area is covered with curved, transparent polycarbonate panels supported by curved and sloped diagonal roof frame pipe members. In order to prevent the "Y" columns from creating a longitudinal truss and still maintain their delicate profiles, the entire roof framing is connected to the Y-columns with bolted "pin" connections. Slotted bolt holes allow for both thermal and bridge bending displacement at each column connection. With partial height glass railings and wind screens, the resultant bridge cross section provides an 11-foot wide bridge deck with outward sloping "walls," and a continuous skylight roof which creates an extremely comfortable and open space for the Lincoln Square shoppers.

Usage of upturned W21x122, ASTM A992, floor girders and a 6-inch deep x 16-gauge metal deck with a 3-inch concrete topping slab provides the necessary bridge mass and stiffness to control foot traffic vibration and movement, with assistance from the 16 stainless steel mast cables which attach to the bottom side of the W21 girders. The bridge cables consist of 12-28mm forestays and 4-36mm backstays

South elevation, completed installation with trunk columns and cables in place

Interior bridge details with Y-columns and polycarbonate panels. Photo by Ben Benschneider



Bridge section

A316 stainless steel cables with custom Ronstan adjustable turnbuckles. Following the AASHTO Guide Specifications for Pedestrian Bridges, the recommended fundamental frequency of 3 to 5 Hz was achieved with a first vertical mode of vibration of 3.1 Hz. Staad Pro 3-D dimensional structural modeling was performed for the entire bridge and support columns above the pile caps.

The bridge was also evaluated against collapse in the event that all cables become damaged. Sufficient strength exists in the bridge deck framing to preclude collapse from its self-weight. The cables were designed without a pre-tensioning requirement and were tightened to support partial bridge dead loads plus full 100 psf live loads and 25 psf snow loads, to suit human comfort and for the bridge dynamic response.

Since the bridge was designed with the new retail facility at Lincoln Square, all longitudinal seismic forces are delivered thru the floor diaphragm and steel chords directly to a single floor coupling connection at the east bridge-building interface. ABKJ engineers designed the pin connection, using a single 2-inch diameter bolt, to transmit the 52 kip longitudinal seismic bridge force directly to an existing building drag strut. Resistance to transverse seismic and wind forces is provided by the "Y" column and bridge diagonal roof pipe frames to deliver transverse forces to the horizontal bridge deck diaphragm, with final distribution to the single "tree trunk" cantilevered columns located near each end of the bridge. In order to express the usage of structural steel throughout, the architect selected "wide-flange" shapes for the built-up tree trunk columns as well as the bridge girders and built-up "Y" columns. Foundations for the entire bridge, provided by 4-foot thick pile caps with 18-inch diameter auger cast piling located directly below each trunk column, react to lateral seismic forces by pile bending. The cantilevered trunk columns taper linearly from the 26- x 16-inch base to 6- x 6-inch at the mast tops, using 1.5-inch thick flange plates and double 1.25-inch thick web plates. ASTM A36 steel was used for the extensive built-up structural shapes. Connection to the concrete pile cap is provided by (8) 3-inch diameter anchor rods.

Fabrication Challenges

Jesse Engineering shop fabricated all of the structural steel members, as well as shop erected the entire bridge full length to ensure correct fit-up and allow the contractor to ship and field erect efficiently and quickly.

Because of the complex geometry, with 3 dimensionally curved members throughout, 3-D AutoCAD computer modeling was employed to develop precise structural steel shop drawings to ensure accurate fit-up. Almost 90% of the bridge members are curved, sloped or skewed in one or more planes. Prior to shipping, the entire bridge structure received 2 coats of Tnemec 1078 air-dried Fluoronar paint followed by field touch up at weld locations.


Installation of prefabricated bridge

Design and Construction Team

Owner
Kemper Development Co.
Bellevue, WA

Structural Engineer
ABKJ Inc.
Seattle, WA

Architect
Sclater Partners Architects
Seattle, WA

Contractor
Skanska USA Building, Inc
Seattle, WA

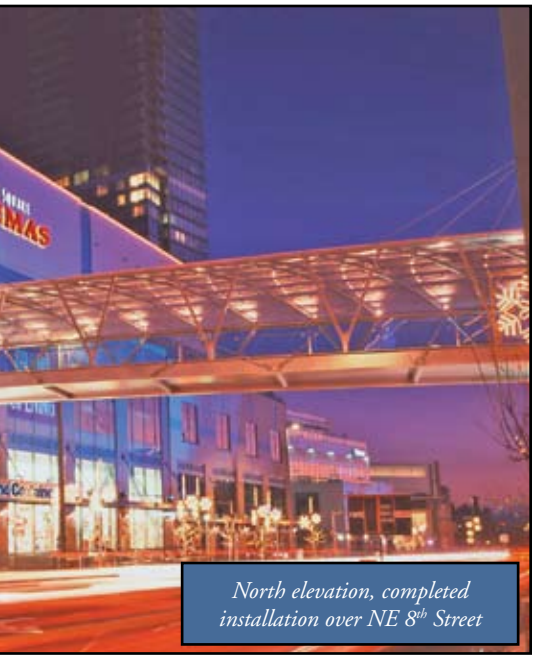
Steel Fabrication
Jesse Engineering
Tacoma, WA

Erection Challenges

The Skanska USA construction team prepared the bridge support piles and pile caps in advance of the bridge shipment, followed by erection of the two trunk columns. Erection of the 65 ton bridge skeleton was accomplished after midnight on a weekend, using two mobile cranes. Because of the excellent fit-

Darren Johnston is a Project Manager at ABKJ. Mr. Johnston provided the structural design and construction administration services for the bridge.

Dennis Baerwald is President of ABKJ Inc, a Seattle based company. A registered structural engineer in Washington, Mr. Baerwald actively participates in the design process on major projects and the quality assurance process on all projects building related.



North elevation, completed installation over NE 8th Street

up between bridge and the trunk columns, the entire erection procedure was finished well before daylight allowing for early car traffic below. Placement of the bridge deck concrete topping slab, roof panels and glass railings followed quickly afterwards to meet the scheduled bridge opening.

Roof framing shop fabrication

Narong Trongtham, a Principal at ABKJ, is a registered structural engineer in the state of Washington. Mr. Trongtham provided project management and design services for both the pedestrian bridge and the adjacent Lincoln Square mixed-use facility.

Conclusion

The new Lincoln Square pedestrian bridge provides a dramatic link between two major downtown Bellevue shopping areas. The architect's desire to express all of the structural components, with an unusual emphasis on a "sculptured" design and individual member detailing, provided the engineers a unique design challenge solved by extensive computer modeling and intensive architect/engineer coordination. The usage of lightweight structural members, cables and transparent sidewalls and roofing accomplishes the owner's desire to achieve an aesthetically pleasing, modern and interesting skybridge for the employees and patrons of both Bellevue Square and Lincoln Square for years to come.▪