Structural Form Nestled Among Majestic Redwoods

Award Winning U.C. Santa Cruz Core West Parking Structure

When officials at the University of California Santa Cruz chose a redwood-covered hilltop for the location of a new campus parking structure, there were formidable obstacles to overcome. Watry Design, Inc. (Redwood City, CA) designed the structure to respond to the sloping site, and to minimize the impact to the environment by modifying the floor plate and incorporating a cantilevered perimeter to save the surrounding trees.

The site chosen for the University's new 500-stall parking structure was an existing 67-stall parking lot nestled among the trees. The award-winning, innovative design of the building greatly improves the utilization of the site while embracing and preserving this natural setting.

The parking structure is a six level, cast-in-place, post-tensioned concrete design. The most distinctive feature of the building is the cantilevered perimeter framing, which was introduced as a mechanism to reduce the footprint of the foundation and protect the roots of surrounding trees. This environmentally sensitive concept led to an innovative structural and architectural solution.

Other unique features include a floor plan that is skewed to preserve existing trees and sloped to blend with the cascade of the hillside. The perimeter rails vary in design and material to accentuate the building transitions while effectively creating a horizontal floor appearance and less massive facade. Seismic resistance is achieved with special beam and column framing, rather than shear walls. This open framing, combined with a central lightwell, creates a comfortable, safe environment for the facility users.

Geometrics

The building was confined to a small lot on a hill and had to be sensitive to particular trees and biotic regions. The following are the geometrics of the structure:

- The structure is divided into quadrants stepped in elevation by 2'-9", and with even sloping of 4.6% between quadrants.
- 8'-6" x 17'-6" typical stalls, 9'-0" x 18'-0" accessible stalls
- 90 degree parking
- 24'-10" drive aisles
- 20'-0" column spacing to allow stalls to nestle between columns
- 499 total stalls in 178,800 square feet; equivalent to 358 sf/stall

Foundation System

The foundation is a concrete mat with deep grade beams. The grade beams are located under the seismic moment resisting frames to increase stiffness and ductility. Drilled piers were originally considered, but were rejected on the basis of uncertain sub-surface conditions. Geological testing and a review of historical information of the area indicated that underground caverns or voids could exist below the site. Should one of these voids be encountered during the drilling operation, an undetermined amount of concrete fill would need to be pumped into them. To avoid the risk of excessive change orders due to unforeseen site conditions, a shallow foundation system was used.

Several precautionary features were incorporated in the mat design to address the potential for underground voids. First, the soil below the mat was over excavated and replaced with engineered fill. The geotechnical engineer on the site determined the depth of the fill. Exposing shallow voids was the primary criteria for the over-excavation. Second, the mat was designed to span or distribute loads across potential voids that may exist below the engineered fill. Last, large column loads were not allowed on the perimeter of the mat. A minimum extension of five feet was required for the engineered fill beyond the foundation. To accommodate this extension without endangering the surrounding trees, all perimeter columns were moved into the interior of the footprint by approximately twelve feet, thereby creating the long cantilevers that characterize the architectural look of the superstructure.

Structural Framing System

The structure is a two-bay single helix constructed using a one-way slab and beam, cast-in-place post-tensioned concrete system. The slabs are 5 ½ inches thick and span 20 feet between beams. The beams are 30 inches deep and extend 12 feet towards the perimeter as tapered cantilevers. Additional reinforcement was provided at the negative moment regions of the cantilevers to reduce cracking and improve durability.

The structure incorporates several other enhancements for improving durability. First, fully encapsulated tendons were used to protect against corrosion. Second, fly ash was used in the concrete mix to remove free lime (mixed with water, free lime can be caustic to automobile paint. Third, the concrete was designed with a low water/cement ratio to reduce shrinkage and permeability. Last, a chemical sealer/hardener was applied to the decks immediately after concrete placement.

Awards:

CRSI Award
2002 IPI Award of Excellence
American Concrete Institute Award

Project Highlights:

493 parking stalls
178,800 total square feet
$9,854,000 total cost
$19,988 per stall
363 square feet per stall
6 total levels, 1 partially below grade
15-foot cantilever around the entire structure
Sloped building to tuck into the hillside
Set amid the forest
Planters at key points to bring in the natural environment
Includes surrounding road/path work

Perimeter Retaining Walls

The structure is nested into the hillside, which is retained by perimeter cantilever retaining walls that extend up to 15 feet. The bases of the retaining walls are connected to the perimeter edge of the mat foundation. Expansion joints designed to accommodate the anticipated seismic displacement separate the walls from the main structure. The need for the separation is two-fold. First, allowing the structure to float within the pocket created by the retaining walls minimizes slab cracking due to volumetric changes of the concrete (e.g., shrinkage, thermal expansion and contraction, etc.) Second, separating the walls from the structure allows the seismic moment resisting frames to function as intended without interference.

Seismic Force Resisting System

The seismic force resisting system is a dual system comprised predominantly of special moment resisting frames. It was not practical to disconnect the elevator walls from the structure, so they were engineered as part of the seismic resisting system. To minimize shrinkage cracking in the slabs, delay strips temporarily separated the elevator hoistway from the structure for 90 days. Also, construction of the wall returns was delayed to temporarily minimize the stiffness of the hoistway and reduce shrinkage cracking.

Special detailing was required for deformation compatibility between the moment frames and the sloping ramp diaphragms. Analytical studies indicated that the stiff inter story strut action created by the ramp diaphragm circumvented the moment frames. In essence, seismic load intended to be resisted by the moment frames was transferred through the ramps instead, and the ramps had insufficient capacity to resist the base shear of the structure. When expansion joints were modeled only at the base of the ramp, soft story and weak story conditions developed as load accumulating in the ramp diaphragm suddenly transferred at the first floor to the moment frames. To avoid these undesirable effects, expansion joints were installed in the ramps at each level of the structure. These separations prevent unintentional lateral loads from circulating through the ramps, and they allow the moment frames to deform as intended and resist loads in a ductile manner.

Interior lightwells were used to avoid short columns at the ramp split. Offset beams in parking structure ramps create short columns that have very little ductility. Given the substantial inter story drifts anticipated from the moment frame system, special design features such as double columns were necessary to avoid the short columns. By separating the double columns, a lightwell was created that enhances the interior space with natural light. This feature of the structure was considered to be a "win-win" by both architects and engineers.

Maintenance

The University has limited maintenance funds and personnel, so long-term durability of the structure was a priority. Parking maintenance personnel regularly maintain the facility by removing any graffiti or debris and insuring that all systems remain operational. The following items were incorporated into the structure for ease of maintenance:

Structural Design Elements –

- Concrete reinforcement above code-minimum levels at locations subject to increased cracking.
- Expansion joints that separate the ramps between each level to control cracking.
- Non-structural walls released from adjoining elements to limit cracking at these areas.
- A chemical sealer/hardener applied to the decks immediately after concrete placement.
- Concrete mix incorporating fly ash to remove any free lime. (Mixed with water, free lime can be caustic.)
- A low water/cement ratio for a high quality concrete mix.

Architectural Design Elements –

- Continuous concrete curbs to facilitate deck cleaning.
- Exposed cast-in-place concrete, which does not require painting.
- Steel rails and pickets were hot-dipped galvanized and were not painted.
- Oversized top deck drains were installed to accommodate redwood tree duff.

The mat foundation was sloped to maintain constant height columns in the moment frames. Analytical studies indicated that variations in column height greatly affected the even distribution of forces within the frame.

Stairs

The stairs are constructed of cast-in-place concrete. The stiff properties of the stair system do not tolerate much lateral drift. To safely accommodate the anticipated seismic inter story drifts, the base of the lower stringer at each level is allowed to slip freely on the supporting slab. Lateral stability is provided at each level by the fixed connection between the upper stringer and the upper slab. Columns at the mid-landing provides additional vertical support.

Planter Boxes

The planter boxes on the floor decks provide visual appeal to the structure. However, these boxes also serve two other important functions. Structurally, the planters are designed as upturned beams to support the floor slab. Architecturally, the planters serve as visual screens to hide the grade changes in the floor slabs. The architectural intent is for the structure to have a terraced look, where each corner of the structure appears level but at a different elevation than the adjacent corner. The planters visually separate the corners and conceal the sloping floor beyond.

Bridges

There are two bridges that connect the structure to the surrounding site. One bridge is for vehicular traffic and the other for pedestrians. They span across a small ravine and are connected to the mat foundation of the main structure. The bridges are made of concrete and the design incorporates the same forming used on the structure. Both bridges were positioned to avoid existing trees.

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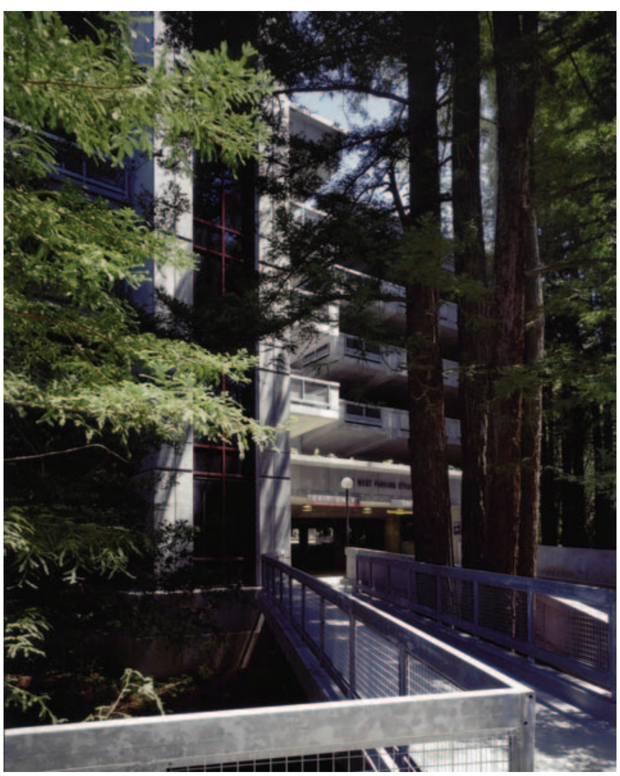

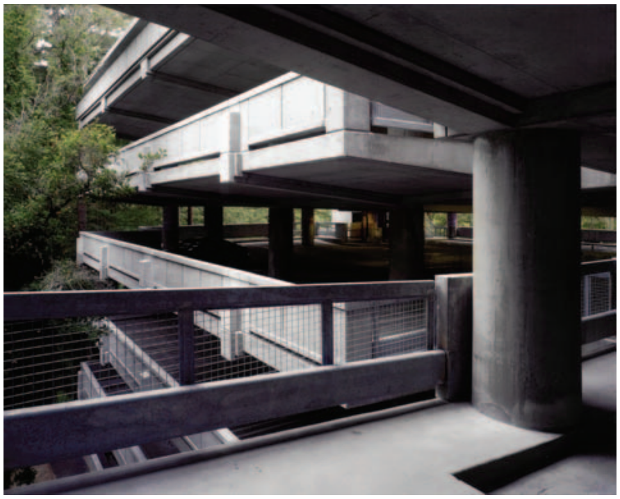

Unique Construction

This building required unique sequencing of the concrete slab pours. Because the floor plates are large, each level was divided into thirds to allow for the best sequencing of formwork. This plan allowed reuse of the custom forms to make construction as efficient as possible.

Conclusion

In the early planning stages, there was local concern about setting such a large building in this environmentally sensitive area. In response, a collaborative design workshop was held on the campus, which included students, faculty, city representatives, architects, and other interested parties. The workshop gave everyone the opportunity to assist in the design process and brought out many creative ideas used in the ultimate design of the structure.

The project team focused on integrating the building's aesthetics within its surrounding environment. The challenge was met… to preserve many of the redwood trees and to visually reduce the actual mass of the structure.

The U.C. Santa Cruz Core West parking structure is an excellent example of structural solutions that address our need to protect and compliment our environment.

Watry Design, Inc., a second generation of Watry Design Group, is one of the largest full service parking structure design specialists in California. For more information, visit www.watrydesign.com

Photography credited to Matthew Millman, Matthew Millman Photography.

Project Team:

Client: UC Santa Cruz
Services: Watry Design Group, Inc.
(Architects, Parking Planners, and Structural Engineers)
Consulting Architect: EHDD Architecture,
San Francisco, CA
Contractor: S.J. Amoroso, Redwood City, CA
Status: Completed March 2001