A cantilevered track lets runners get around Cal State Poly's new state-of-the-art recreation center.

On the Right TRACK

BY DANIEL WANG, S.E. AND BRYAN SEAMER, S.E.

Photos: LPA, Inc./Costea Photography

THE BRONCO RECREATION and Intramural Complex (BRIC) keeps California State Polytechnic University, Pomona's, 24,000 students in shape and on campus.

Funded entirely by student fees, the 165,000-sq.-ft recreation complex is the hub of student activity on the primarily commuter campus. It was designed to be a place where student commuters could work, exercise and socialize between classes, reducing vehicular trips to and from the university.

BRIC includes an aquatic center and a three-story, 95,000-sq.-ft recreation center incorporating five fitness and multi-purpose studios, three basketball/volleyball courts, a multi-activity court, a one-quarter-mile running track, a 51-ft rock-climbing wall, two racquetball courts, administration offices, locker rooms and shower facilities. The dramatic three-story steel structure—which uses 2,200 tons of steel in all—seems to defy gravity even more than the rock climbers inside, featuring several substantial cantilevered floor areas, the longest of which extends nearly 60 ft.

Daniel Wang (dwang@lpainc.com) is an associate and design director of structural engineering, and **Bryan Seamer** (bseamer@lpainc.com) is an associate and managing director of structural engineering, both with LPA, Inc.

Awkward Site, Innovative Building

The architects and engineers of LPA incorporated the large program into an awkwardly shaped site limited by existing easements, setbacks, challenging topography and a less than optimal building orientation. Utility easements surround the site and a major underground utility corridor runs between the pool facility and the gymnasium complex, restricting the locations where the large recreation building can actually touch the ground. On top of that, the project site is located in a hilly area with a grade differential of approximately 14 ft between the north and south ends of the recreation building. Instead of approaching these aspects as limitations, the design team used them as driving forces to shape the form of the building.

BRIC opens at the intersection of major pedestrian paths converging at the building's main entry with a naturally ventilated lobby that acts as a transition between the unprotect-

The three-story steel structure uses 2,200 tons of steel in all. The design team was tasked with incorporating the building into an awkwardly shaped site with many limitations.

ed exterior and the conditioned interior spaces beyond. The complex frames and makes a direct connection to the adjacent campus quad creating expansive views by opening up to them visually with a three-story façade primarily composed of protected glazing.

The recreation center touches the ground with a footprint confined by existing underground utilities. The building naturally extrudes vertically from this relatively small base around a central high-volume rock-climbing lobby then expands horizontally once above the hidden site constraints. To accommodate the program, the fitness and multi-purpose studios and locker facilities are located on the first floor. The column-free basketball and volleyball courts are located on the second floor and the one-quarter-mile running track traverses the perimeter of the third floor exercise and weightlifting area. The running track on the top floor affords joggers a continuous scenic view of the campus and surrounding areas.

Building as Diving Board

The natural topography along with the requisite size and shape of the second-floor sports courts dictate that the third floor and roof structure cantilever horizontally from the supporting building base below along three sides of the building. The double-cantilevered northeast corner of the building cantilevers 57 ft to the north and 32 ft to east, floating placidly above a landscaped garden and pedestrian walk below.

While the need for the long double cantilever was created by existing underground obstacles, the engineering challenge was compounded by the new building's program. With two-story basketball and volleyball courts on the second floor creating two very large openings in the third floor, there is no "back span" available to counter-balance the large cantilevered floor areas making a conventional single-floor cantilever beam framing system impossible.

Further, to cantilever the gymnasium floor nearly 60 ft, serviceability criteria become paramount to the design, with deflection and floor vibration shaping the steel

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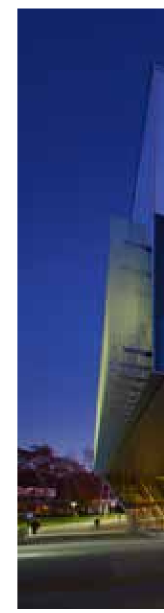
▲ ▼ ➤ The long cantilevers are supported by a combination of two-story Vierendeel trusses and heavy steel plate girders at the roof. The heaviest steel plate girder is 9 ft deep, with a weight of approximately 82.5 tons.



framing much more than steel member strength. The long cantilevers are supported by a combination of two-story Vierendeel trusses and heavy steel plate girders at the roof. The built-up steel plate girders are located at the roof level where larger back spans are able to counterbalance the deflection at the cantilevered building corner. The third floor hangs from these plate girders, taking advantage of the rigid framing at the roof to control floor deflection and vibration. Due to the long cantilever, the plate girders are truly massive for a building of this size. The heaviest steel plate girder is 9 ft deep, with a weight of approximately 82.5 tons.

To further reduce the floor deflection, the roof and third-floor framing and the columns between them are connected with fully-rigid welded connections to form two-story Vierendeel trusses along the building perimeter and at strategic locations within the interior of the floor. Even though the structure is located in a very seismically active region in Southern California, the structural steel members in the buckling-restrained braced frame (BRBF) seismic load resisting system are significantly smaller than those supporting the huge cantilevers.

Project Team Jogging Club

In order to accommodate a one-quarter mile circuit, the running track loops around the perimeter of the third floor, traveling directly over all of the ends of the cantilevered building corners. As such, these long cantilevers have to withstand significant gravity-induced deflection and are very sensitive to vibration excited by each step of a runner on the track. Like wind blowing on a multi-story high-rise building, the cantilevered floors could sway when a runner's footfalls pound the synthetic pavement. Occupant comfort as well as deflection control to avoid damage to exterior building skin attachments played a crucial part in the design of the steel floor system.

This design challenge was tackled both analytically and empirically. During the design phase of the project a floor vibration analysis was performed based on recommendations for human comfort and rhythmic vibration found in AISC's Design Guide 11: *Floor Vibrations Due to Human Activity*. A 3D SAP 2000 finite element computer model was constructed to analyze the vibration of the floors, and the rhythmic runner heel drop motions were simulated by placing impulse loading at various points along the running track in the SAP 2000 model. In one of the studied scenarios, the adjacent impulse loads are input

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The 51-ft rock-climbing wall.

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with a two to three-second delay to simulate the typically random, out-of-phase nature of a group of runners on the track. Several scenarios were modeled to approximate as many natural running conditions as possible. Inherent damping of two percent of critical damping was assumed because the third floor lacks full-height partitions and features a generally open floor plan. The resulting peak floor accelerations and amplitudes were compared to the recommendations for occupant comfort suggested the design guide to optimize the steel framing design. The natural frequencies of the cantilevered building corners were tuned so that they avoided excitation by the rhythmic forcing frequency of the running motion simulations.

In order to verify that the steel floor design adequately accounted for the unique vibrational performance criteria, the design team field tested the floor during construction. After all the structural steel and concrete decks were in place, a series of on-site floor vibration measurements were conducted to verify that the predicted results of the analytical vibration study were accurate. While the measurement was conducted using very precise and sensitive equipment attached to the floor, the excitation was created by inviting the project team, including designers, constructors and the client to run laps around the track. The results confirmed that the actual floor acceleration values were within the design guide's comfort limits and that the natural frequencies were nearly identical to the predictions of the computer analysis conducted prior to construction.

Completed last fall, BRIC fits right into its surroundings and is built to withstand whatever forces are imposed on it. ■

Owner
California State Polytechnic University, Pomona

General Contractor
CW Driver

Architect and Structural Engineer
LPA, Inc.

Steel Team

Fabricator and Erector
The Herrick Corporation, Stockton, Calif.

Detailer
SNC Engineering, Inc., Compton, Calif.