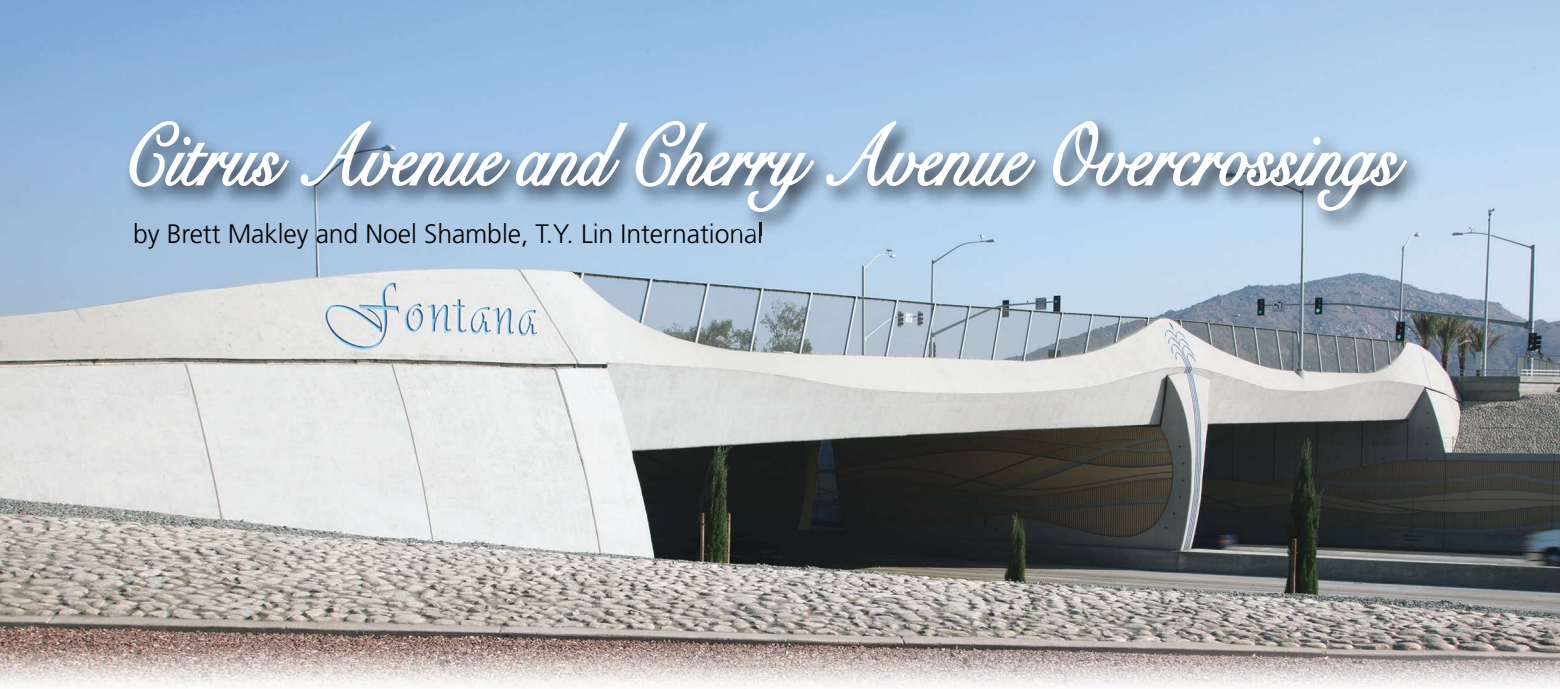
Citrus Avenue and Cherry Avenue Overcrossings

by Brett Makley and Noel Shamble, T.Y. Lin International



Citrus Avenue Overcrossing. Photo: Tom Paiva.

Architectural ingenuity and structural resilience came together to create two landmark overcrossings for the city of Fontana, Calif. The two bridges incorporate characteristics of the local community, serve as gateways to the city, and are able to withstand the effects of an earthquake in the seismically active region of southern California. The Citrus Avenue Overcrossing and the Cherry Avenue Overcrossing, located just 2 miles apart along Interstate 10 (I-10) in the county of San Bernardino, are two important components of two full-interchange reconstructions.

Improvements to the interchanges were needed to alleviate congestion and ease the heavy truck traffic that travels from the Los Angeles area ports easterly through California to other states. The San Bernardino Associated Governments (SANBAG), in cooperation with the city of Fontana, the county of San Bernardino, and the California Department of Transportation (Caltrans), led the effort to reconstruct the interchanges.

The project included

- replacing the existing overcrossings with wider and longer cast-in-place prestressed concrete box girder structures,
- widening the existing precast-prestressed concrete I-girder overcrossing structures over Union Pacific Railroad's tracks, and
- widening and improving the on- and off-ramps to I-10.

The I-10/Citrus Avenue Interchange was completed in the spring of 2014. It will soon be followed by improvements to the I-10/Cherry Avenue Interchange, which is expected to be completed by early 2015. The overall project—which must be completed on-time to meet strict, accelerated funding deadlines—includes four bridges, new loop ramps, numerous retaining walls, and a major drainage channel.

Construction

The operational capacities of the original interchanges, both of which were constructed to rural standards in the 1950s, were severely challenged by the large volume of traffic created by subsequent development in the city of Fontana. To minimize traffic impacts in the area and maintain existing traffic flow, a two-stage construction technique was implemented. First, half of the new bridge was constructed parallel to the existing structure. For the overcrossings, the existing structure was then demolished and replaced. For the overheads, the existing structure was overlaid with a combination of polyester concrete and structural concrete to match the deck grades of the widening. For both structures, the two halves were connected with closure placements to create one continuous structure at each location.

Aesthetic Starting Point—Cherry Avenue Overcrossing

The starting point for the architectural design of the Cherry Avenue and Citrus Avenue Overcrossings was site context. The first structure to be developed was the Cherry Avenue Overcrossing. The stakeholders wanted an eye-catching design that would reflect the city of Fontana's growing community, while providing a special gateway for the

profile

CITRUS AVENUE AND CHERRY AVENUE OVERCROSSINGS / FONTANA, CALIFORNIA

BRIDGE DESIGN ENGINEER AND ARCHITECT: T.Y. Lin International, San Diego, Calif.

PRIME CONTRACTORS: Cherry Avenue Interchange: Ortiz Enterprises Inc., Irvine, Calif.; Citrus Avenue Interchange: Brutoco Engineering & Construction, Fontana, Calif.

PRECASTERS: Cherry Avenue Overcrossing: Coreslab Structures Inc., Perris, Calif.—a PCI-certified producer; Citrus Avenue Overcrossing: Oldcastle, Perris, Calif.—a PCI-certified producer

POST-TENSIONING CONTRACTOR: Dywidag Systems International USA Inc., Long Beach, Calif.

nearby Auto Club Speedway racetrack. Because Cherry Avenue is the racetrack-entrance road, stakeholders wanted the structure to be a visual landmark for everyday I-10 travelers, avid race fans, and even NASCAR national TV coverage.

With the racetrack aesthetic theme, the shape of the structure had to imply the characteristics of a racecar without creating an overly literal caricature. Having a static object convey elements such as speed, power, and motion proved to be an exciting challenge. Using modern car designs for inspiration, the team was drawn to the fluid lines on the sides of many car bodies, made by precise pinches, creases, and three-dimensional curves. Such car panels are made by running a flat, rigid piece of sheet metal through a highly-involved mechanized process.

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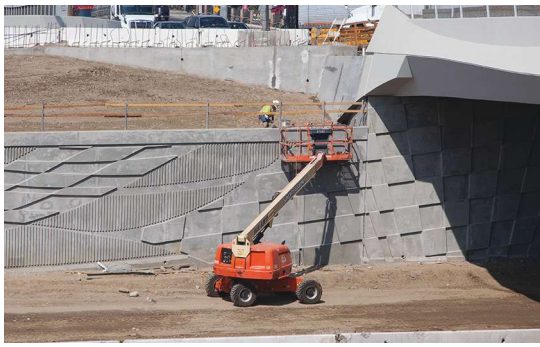
Concrete, alternatively, has the advantage of having fluid and flexible characteristics when being placed, allowing it to convey motion more easily than a static solid. This set the team on a path of exploration based on concrete's inherent material properties. The goal was for the final solid form to reflect both the fluid behavior of the concrete placement process and the fluidity of a speeding racecar. The team was especially inspired by the latest developments in concrete form-making, such as the fabric-formed concrete process, which uses flexible geo-textile materials to create amorphous shapes.

The team arrived at the governing design strategy by combining these explorations of form with both the practical requirements of structural design (such as crash barrier safety, reinforcement layout, and the like) and an understanding of the conventional tools and techniques available to construction crews. The Cherry Avenue Overcrossing has a custom barrier that is triangular in cross section, but which follows fluid, curvilinear paths in elevation. The three-dimensional result is a constantly changing, doubly curved surface. These warping surfaces catch the light differently depending upon the view angle, producing gradients of shade and reflectivity across the structure that create intrigue at a detailed level (without using a form-liner pattern), enhance the modern aesthetic, and reinforce the overall association with movement.



Architectural features of the Cherry Avenue Interchange including walls, abutment, and overcrossing shown during construction, prior to color staining. Photo: Tom Paiva.

Cherry Avenue Overcrossing during construction. Photo: Tom Paiva.

Cherry Avenue Overcrossing during construction. Photo: Noel Shamble.

CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS) AND THE CITY OF FONTANA, OWNERS

BRIDGE DESCRIPTION: Citrus Avenue Overcrossing: 238-ft-long by 166-ft-wide, two-span, cast-in-place post-tensioned concrete box girder superstructure, with span lengths of 134 and 104 ft, with high-seat abutments and a two-pierwall bent on spread footings; Cherry Avenue Overcrossing: 237-ft-long by 127-ft-wide, two-span, cast-in-place post-tensioned concrete box-girder superstructure, with span lengths of 133 and 104 ft, with high-seat abutments and a four-column bent on spread footings

BRIDGE CONSTRUCTION COST: Citrus Avenue Overcrossing: \$4.7 million (\$155/ft^2), project cost \$32 million; Cherry Avenue Overcrossing: \$5.4 million (\$180/ft^2), project cost \$49 million

Citrus Avenue Overcrossing barrier during construction. Photo: Brett Makley.

Citrus Avenue Overcrossing Aesthetics

While the Cherry Avenue Overcrossing is the landmark for the racetrack, the team was asked to make the Citrus Avenue Overcrossing, one exit away, the gateway for the city of Fontana. Using the same fluidity concept and doubly curved barrier architecture, the city's fountain logo inspired the aesthetic theme. The central pier wall ascends and integrates into the custom barrier to create a strong, vertical motion, like the upward spouting of a fountain. From that raised central position, the curvilinear barrier lines flow out like gentle waves. As with the Cherry Avenue Overcrossing design, the abutments bulge outwards to convey a sense of strength and clear visual anchorage.

Additional Aesthetic Considerations

To further expand on the freedom of designing a custom barrier, the team also wanted to challenge the standard conventions of the relationship between the barrier wall and the barrier fence. At some point on both the Cherry Avenue and Citrus Avenue Citrus structures, the concrete barrier rises up to the full height of the 9-ft-tall fence. This not only allows the barrier to make a more pronounced statement to highway traffic below, but it also provides special gateway elements for travelers on the overcrossings themselves. Travelers pass between elements instead of just driving or walking over the highway. This visual and spatial cue is what makes

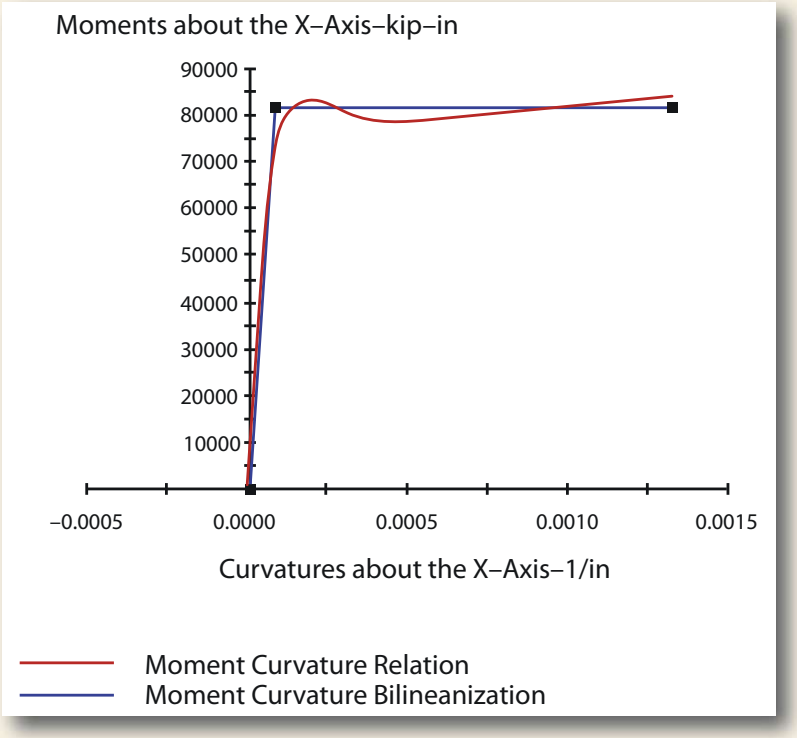
Resilience

The state of California is a highly active seismic area, especially in the fault-ridden area of southern California, making seismic resiliency one of the most critical elements of any infrastructure design. California Department of Transportation's (Caltrans') *Seismic Design Criteria* governs the seismic design of bridges in California, which supplements American Association of State Highway and Transportation Officials' (AASHTO's) criteria to meet the unique challenges of this state. Included in the criteria is a no-collapse standard to ensure that bridges will remain standing after a credible seismic event, even if the structures suffer substantial damage.

One of the key concepts of this standard is to focus the seismic energy of an earthquake into predetermined locations. In concrete bridges, this is typically done by forcing the top and/or bottom of the bridge columns and pier walls to experience and withstand displacements beyond the elastic state by forming a plastic hinge. By allowing and forcing a plastic hinge in certain locations, the damage caused by an earthquake is essentially focused there, allowing the engineer to design accordingly.

The Citrus Avenue Overcrossing substructure is comprised of two concrete pier walls (with design compressive strength of 3.6 ksi), 3 ft thick at the base with nonintegral architectural flares of 6 ft at the top. The Cherry Avenue Overcrossing substructure consists of four 5-ft-diameter octagonal columns (with design compressive strength of 3.6 ksi), with non-integral architectural flares in the transverse direction of 10 ft at the top.

The tops of the columns and pier walls are integral with the superstructure, thereby creating a location for the plastic hinges to form. In both cases, however, the base of the columns and pier walls are pinned to the footings to avoid transferring the large demands of the plastic hinge into the footings and limit the pressure on the foundations. Moment-curvature analyses were performed to help determine the displacement capacity of the plastic hinges, which were then compared to the seismic displacement demands to confirm their structural integrity.



Sample moment-curvature analysis. Figure: T.Y. Lin International.

a "gateway experience," and ultimately makes a place memorable.

In addition to the bridge architecture, the look of the many walls along the highway was an important component of the project's overall visual impact. Working with the Caltrans District 8 Landscape Architect, the team developed a detailed series of flowing, interweaving curvilinear lines that would complement both structures. The success of the fluidity concept, which governed the wall and overcrossing aesthetics of both projects, was thoroughly embraced by Caltrans District 8, which covers Riverside and San Bernardino counties. The design is now the new master theme for the aesthetic redesign of the entire I-10 San Bernardino corridor.

Brett Makley is a senior bridge engineer and Noel Shamble is a bridge architect with T.Y. Lin International in San Diego, Calif.

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AESTHETICS COMMENTARY

by Frederick Gottemoeller

Communities often ask that a prominent bridge in their community illustrate some community landmark or characteristic, or ask that it serves as an icon of their community. With major bridges, the main structural element itself, say an arch or cable stay tower, usually serves this need. With typical highway overpasses, the structural elements are not large or particularly distinctive, which leads designers to look elsewhere for something unique.

One typical response is to use formliners to make the concrete surfaces look like some other materials that are traditional in the area. Or specific images might be inset into the concrete, say a dolphin in a waterfront community or a bison in a western environment. Or a bridge in an historic community might be festooned with antique-looking streetlights designed to look like those from the nineteenth century. Sometimes the effort even includes miniaturized versions of an arch or a cable stay tower with actual miniature stays, hoping the pattern will have an impact even when the size isn't there.

With these two bridges, their designers took a different tack. Recalling that concrete starts out in a fluid state, and realizing that recent experimentation in forming techniques have begun to free concrete from the restrictions imposed by flat plywood sheets, they decided to investigate whether the bridge itself could be shaped to meet the symbolic goals of the community. They sculpted the concrete into abstract shapes calling to mind the cars on the racetrack and the fountain that is a key part of Fontana's identity. The shapes are large enough to be appreciated even by drivers moving at 70 mph. The abstraction even extends to the retaining walls, where a wavy line calls to mind water more effectively than a whole school of inset fish.

The next challenge will be to use these new forming techniques to shape the structural concrete itself to more efficiently carry the forces on the structure. Natural shapes might be the best model. There are many amazing natural structures built without a single sheet of plywood.