# Innovative Prestressed Concrete Bridges Mark Caltrans Centennial

*In this centennial anniversary of Caltrans, the authors trace the evolution of bridges in the State of California and describe an important research program and new initiatives that will insure a bright future for California's bridges.*


**Eric Thorkildsen, P.E.**
Senior Bridge Engineer
Imbsen & Associates, Inc.
Sacramento, California
Formerly, Senior Bridge Engineer
California Department of Transportation
Sacramento, California



**Jay Holombo, P.E.**
Graduate Research Assistant
Division of Structural Engineering
University of California at San Diego
La Jolla, California


In 1895, the State of California first established a State Bureau of Highways Commission. The California Department of Transportation (Caltrans) is currently celebrating this centennial by reflecting back on its history and achievements and also looking towards the future.

A major technological breakthrough in the evolution and development of highways in California was the introduction of prestressed concrete in structures more than 44 years ago. What started out as an experiment in 1951 has exploded into the construction of thousands of prestressed concrete bridges on the California highway system.

Currently, 85 percent of all bridges constructed in California use prestressed concrete. While the majority of recent bridges constructed in California have cast-in-place post-tensioned box girder superstructures, recent developments in precast, prestressed concrete technology has set the stage for a return to the early days when precast concrete was the dominant structure type.

## FIRST PRESTRESSED CONCRETE BRIDGE

The first prestressed concrete bridge built in California can be defined in modern terminology as a precast segmental bridge. Constructed in 1951 (near Los Angeles), the Arroyo Seco pedestrian bridge joined two 55 ft (16.8 m) precast segments together at midspan (see Fig. 1). A temporary falsework bent provided support until the post-tensioning was completed.

This lightly loaded simple span bridge over a flood channel was a conservative first application of prestressed concrete technology (see Fig. 2). The bridge was designed and checked by two legends in the field of prestressed concrete, Caltrans engineer Jim Jurkovich and University of California at Berkeley professor T. Y. Lin.

Dr. Lin turned the bridge into an on-site laboratory by placing strain gauges at key locations on the structure to check the predicted stresses and deformations. The "Proof Test" was successful, and confidence in de-

Fig. 1. Construction of the Arroyo Seco Pedestrian Bridge, the first prestressed bridge in California.

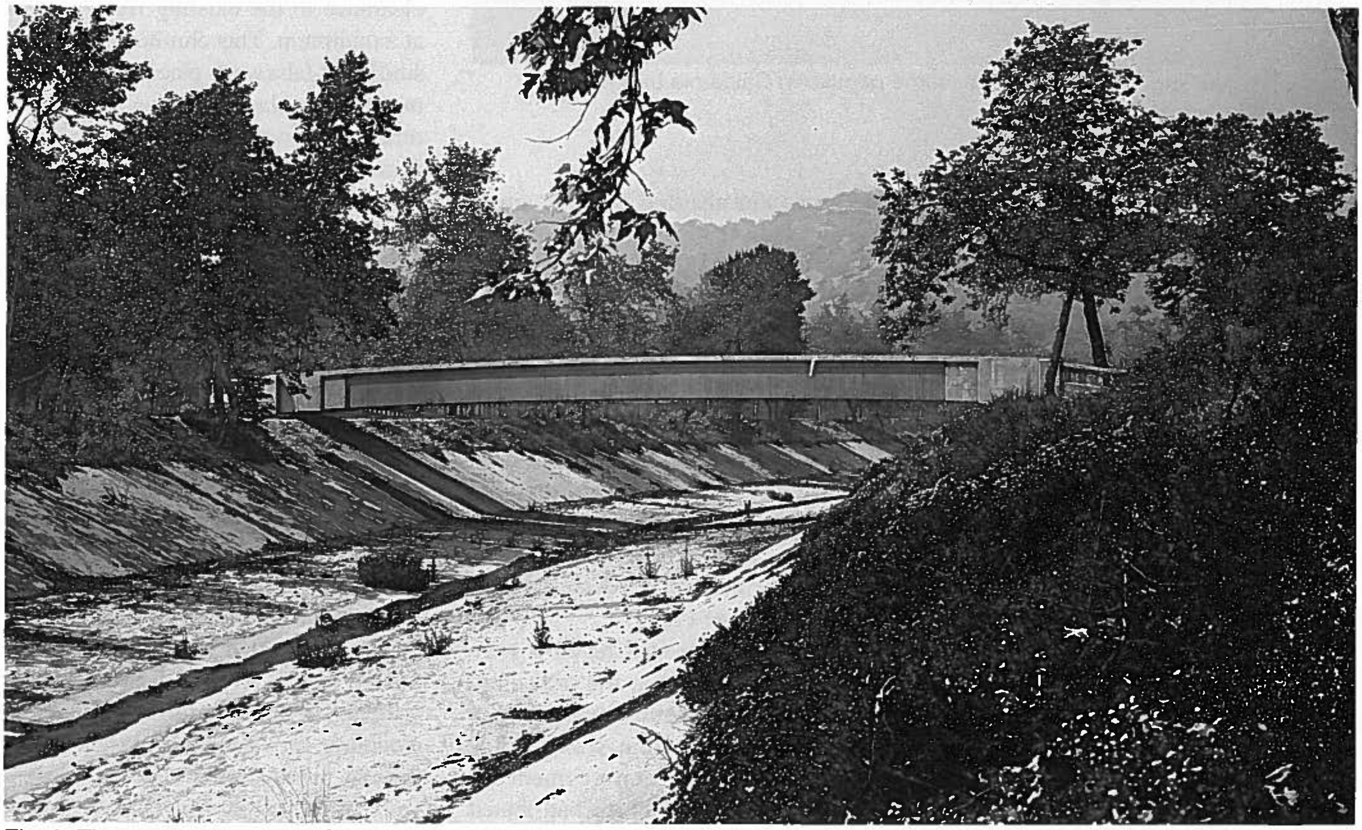

Fig. 2. The completed Arroyo Seco Pedestrian Bridge.

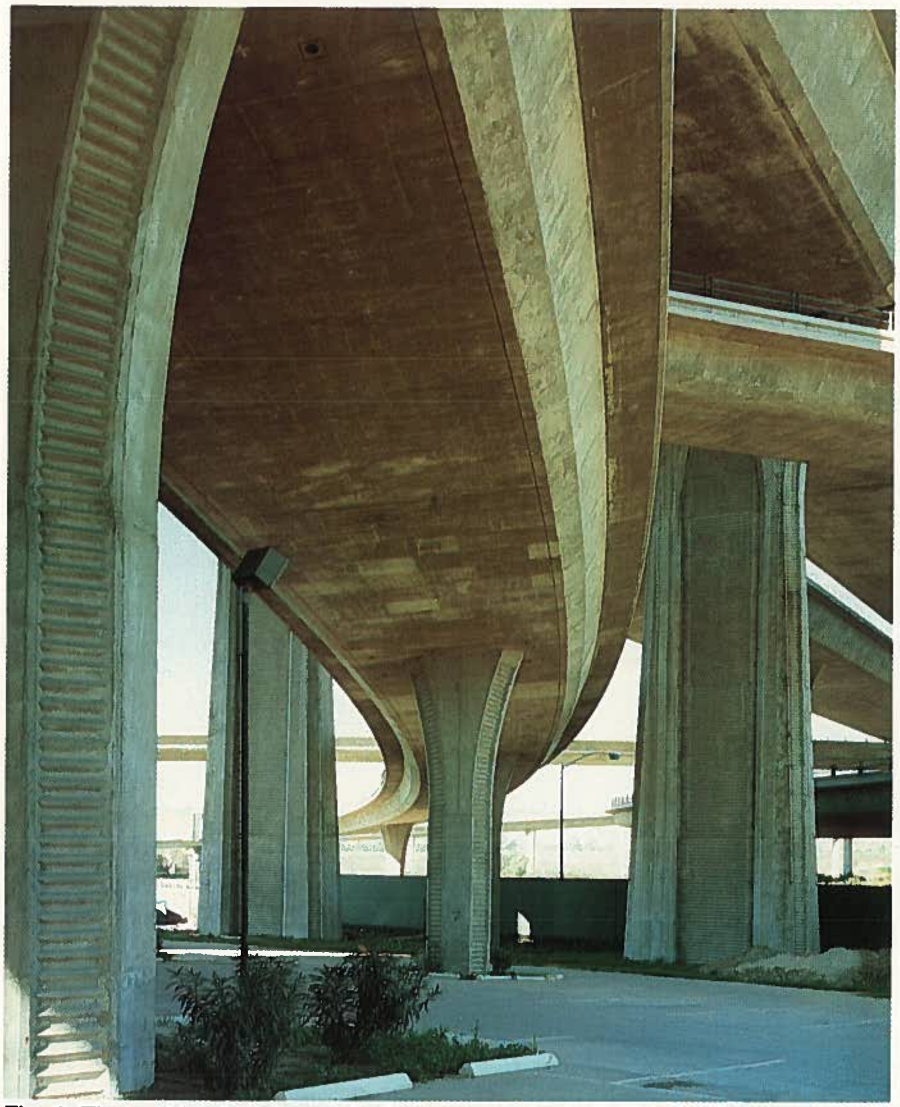

Fig. 3. The cast-in-place box girder became popular in California bridge construction.

sign gained rapidly. Within two years, a prestressed concrete bridge was constructed in Fresno to carry heavy truck traffic over a congested highway. Many California bridge engineers soon considered prestressing "just another familiar construction method."

## CAST-IN-PLACE PRESTRESSED BOX GIRDER

Prestressed concrete bridges in the early 1950s were precast and used mainly in special situations, such as to work around site constraints on falsework placement, to speed up construction, and to meet roadway vertical clearance restrictions that required more slender superstructures. The economic rule of thumb in those days for structures not affected by such situations was to use the conventionally reinforced cast-in-place T-girder structure type for spans less than 100 ft (30.5 m) and the conventionally reinforced box girder for spans greater than 100 ft (30.5 m). By 1956, the controlling span length decreased to 80 ft (24.3 m) as the box girder's popularity grew. Contractors preferred the flat platform falsework surface for the box girder and the cheap material used to form the interior girders reduced overall costs (see Fig. 3).

Because concrete forming costs were much less for the box, the only item restricting all around use of this superstructure system was the increased amount of reinforcement required. The reduction of steel attributed to the new prestressing technology quickly solved this problem.

California contractors invested heavily in the falsework needed for cast-in-place construction. Once this initial investment was made, the cost of cast-in-place construction dropped to a level at or below precast girders. The seismic resistance and aesthetics of the box girder gained favor among designers. The cast-in-place post-tensioned concrete box girder became California's favorite bridge.

## PRECAST GIRDERS SOLVE DIFFICULT PROBLEMS

While cast-in-place construction was feasible for new highway alignment in uncongested areas, an increasing number of bridges required innovative solutions using precast concrete. A safety program, begun in the 1960s to eliminate bents directly adjacent to roadways, provided constraints that only a precast, prestressed concrete option could accommodate.

Many four-span overcrossings were replaced with two-span structures, eliminating the end bents nearest to the abutment. The existing roadway profiles could not be altered and vertical clearance to the existing freeway was at a minimum. This eliminated the possibility of falsework placement and demanded a replacement two-span structure depth comparable to the existing four-span type. Half-span segments were precast and erected at night on temporary supports while the freeway was closed. They were immediately post-tensioned together, the support removed, and the freeway was clear and open to traffic by the next morning. The solution was very successful.

Further growth within the populated regions of California, such as San Francisco, brought about new difficulties for cast-in-place construction. Interstate 280 in the China Basin area of San Francisco, constructed in the 1970s, used hundreds of precast girders for its elevated viaduct (see Fig. 4). Many more bridges needed to be widened with no additional vertical clearance for falsework placement, so precast pretensioned concrete girders were often the choice. Precast girders were erected over environmentally sensitive bodies of water and became the preferred structural type to span over or carry rail traffic. Although it remained the minority bridge system during this time period, precast concrete bridges filled an important gap.

## PRESENT NEED FOR PRECAST BRIDGES

Special situations that historically required precast construction are now very common in California. Growing congestion, environmental concerns, and speed of construction are just a few of the contributing factors. Caltrans is currently working in close cooperation with the precast concrete industry to develop technologically advanced precast bridges that feature many of the desirable characteristics found in cast-in-place post-tensioned concrete box girder bridges. These characteristics include continuous post-tensioning, seismic resistance, aesthetic appeal, and a low depth-to-span ratio.

Although the California I-girder would still be the workhorse for spans less than 125 ft (38 m), a new girder was needed for longer spans that could be spliced together to take advantage of the low depth-to-span ratios offered by continuous post-tensioning. The bulb tee structure shape had been routinely used in other states for typical bridge spans ranging from 150 to 180 ft (45.7 to 54.8 m), but lacked the aesthetic appeal of the cast-in-place box girder. The precast delta girder, historically used in aesthetically sensitive locations, was considered uneconomical due to its heavy weight. A type of delta girder without a precast deck slab, currently used in Canada, Oregon, Washington, and Texas, was then considered. This type of structural shape, called the "Bathtub" in California, was chosen to be the next generation precast concrete girder shape.

The bathtub girder was not the definitive precast solution for all problems. This girder still required temporary falsework bents until the initial post-tensioning was complete, was heavier and more costly than the bulb tee, and would be difficult to continuously mount over a support bent. Caltrans decided that two distinct precast concrete girder types, the bulb tee and bathtub, should be developed.

Fig. 4. The Route 280 Viaduct in San Francisco, built in the early 1970s, used large quantities of precast prestressed girders.

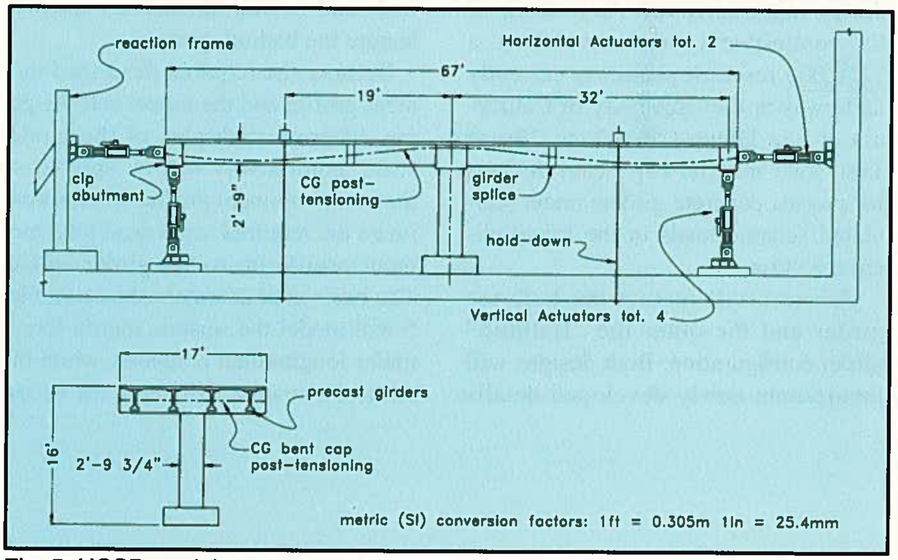


Fig. 5. UCSD model test setup.

## SEISMIC CONCERNS

Current Caltrans seismic design policy requires superstructures to elastically resist plastic hinging demands from the column. This leads to more manageable repairs and presumably allows continued traffic flow. A rigid type of connection at the column superstructure interface allows the column to better resist lateral seismic forces. Past designs for precast girder bridges were suspect in these areas. The design usually consisted of a cast-in-place inverted T-bent cap with notched precast girders seated on the cap. The deck was continuous over the bent, but there was no effort to obtain the kind of positive moment connection needed to resist column hinging demands.

The lack of a rigid connection at the column superstructure connection becomes evident when considering a typical bridge with multiple support columns per bent. A cast-in-place box girder bridge with an integral column cap connection would not require a moment resisting connection at the column footing interface, whereas the precast bridge would. The size of the substructure elements, such as the footing and piling, can be drastically reduced, resulting in significant cost savings. This column superstructure connection became the critical detail in the precast concrete girder's resurgence in popularity.

## RESEARCH AT UCSD

To solve such difficult problems, a joint technical committee was formed between Caltrans engineers, outside consultants, and precast concrete industry representatives. As a result of the committee's recommendation, a $250,000 research project is currently underway at the University of California at San Diego (UCSD) to "Proof Test" two integral cap beam designs for precast concrete girders under simulated seismic loads in the longitudinal direction.

One test will feature the bulb tee girder and the other the "Bathtub" girder configuration. Both designs will incorporate newly developed details designed to increase the width of the superstructure effective in resisting the plastic overstrength moment of the column, reduce reinforcement congestion in the joint region, and increase the cap beam torsional capacity.

Design and construction of the first model to be tested has begun and is shown in Fig. 5. This is a $^4/_{10}$-scale, or 40 percent full scale, model of a typical single column bent including the column, footing, cap beam, and tributary modified bulb tee girders extending midspan to midspan with composite decking. Precast girder segments will pass through the cast-in-place post-tensioned cap beam and splice in the general location of the dead load inflection points.

Continuous girder post-tensioning will pass through the girder segments and will be jacked at the anchorages located in the abutments at either end of the model. Because the cap beam is deeper than the superstructure, mild reinforcing steel will pass under and over the girders and only the post-tensioning tendons need to pass through the girders in the cap beam region. The second model will have a similar scale and overall dimensions and will feature the bathtub girder.

Because the required dead load moment profile and the model self weight are different multiples of the model scale, hold-downs will be applied so the model moment profile will approximate the required scale dead load moment profile up to the girder splice. The horizontal actuators shown in Fig. 5 will model the seismic inertia forces under longitudinal response, while the vertical actuators will apply the necessary dead load and seismic shears into the girders.

Testing of both units will consist of incremental horizontal fully reversed displacement cycles until target ductilities have been reached. If a successful response is observed, the majority of the damage will occur in the column with only minor distress in the superstructure elements and cap beam elements. Therefore, a second part of the test will involve disconnecting the horizontal actuators and loading the vertical actuators to failure to observe the force displacement response of the composite superstructure.

Construction of the first unit started in the beginning of September of this year and testing is scheduled for the first part of January 1996. The second unit is scheduled for testing in March or April of 1996. Data reduction of the extensive instrumentation planned for both tests and reporting will be completed several months after testing.

## CONCLUDING REMARKS

With the completion of the research at UCSD and the standardization of these designs, California could once again benefit from precasting segments and continuously post-tensioning them together using the same concepts developed for the Arroyo Seco pedestrian bridge 44 years ago. Together with all the other innovative technological advances that are occurring in seismic design, construction techniques and new materials, the future of bridge building in California does indeed look bright.