Presidio Viaduct

South Access to the Golden Gate Bridge

by Ahmed M. M. Ibrahim, John F. Walters, and Ofelia P. Alcantara, California Department of Transportation (Caltrans)

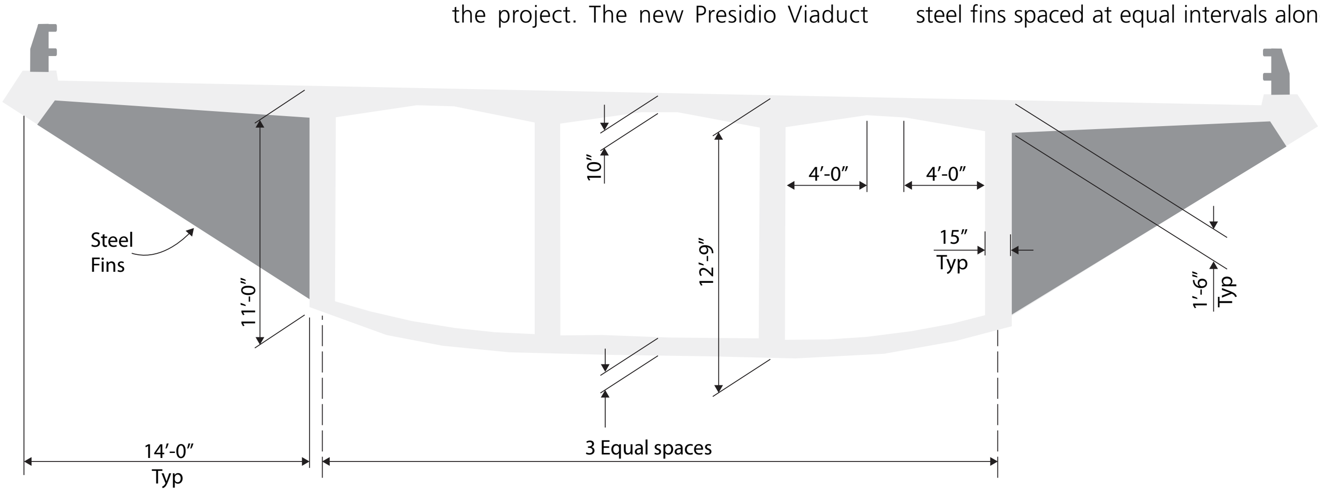
Rendering of the Presidio Viaduct. All photos, drawings, and rendering: Caltrans.

The existing south access road to the iconic Golden Gate Bridge, known as Doyle Drive, is structurally and seismically deficient and needed to be replaced. The roadway is facing the same problem that threatens other parts of our nation's infrastructure—the ravages of time and heavy use. Originally built in 1936, Doyle Drive has reached the end of its useful life.

The Presidio Parkway project, the Doyle Drive replacement, will result in a dramatic visual and structural change for the corridor. The $1.045 billion project is divided into two phases. The first phase, currently underway, involves construction of one of two new viaducts, one of four cut-and-cover tunnels, and an at-grade temporary bypass at the eastern end of the project. The new Presidio Viaduct currently under construction is one of the landmark structures of this extensive project.

Several bridge types were considered during the design phase, including parabolic, prestressed concrete box girders, steel tubular trusses, and Warren steel trusses with composite concrete deck and soffit.

The selected bridge is a six-span, cast-in-place, prestressed concrete box girder with three main spans of 275 ft (Spans 2, 3, and 4). Spans 1, 5, and 6 have lengths of 188 ft, 184 ft, and 143 ft respectively, resulting in a total bridge length of 1340 ft. The bridge has a uniform superstructure depth along its length, with the depth varying transversely. The depth is 12.75 ft at the middle of the cross section, but curves upward to a depth of 11 ft at the face of the exterior webs. The superstructure cross section includes a 14-ft deck overhang on each side with architectural steel fins spaced at equal intervals along



Typical cross section of Frame 1.

profile

PRESIDIO VIADUCT / SAN FRANCISCO, CALIFORNIA

BRIDGE ENGINEER: California Department of Transportation, Sacramento, Calif.

PRIME CONTRACTOR: CC Meyers Inc., Rancho Cordova, Calif.

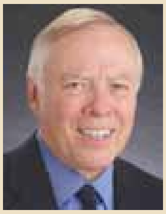
CONCRETE SUPPLIER: CEMEX, San Ramon, Calif.

POST-TENSIONING SUPPLIER: Schwager-Davis Inc., San Jose, Calif.

REINFORCEMENT SUPPLIER: Harris Salinas Rebar Inc., Livermore, Calif.

AESTHETICS COMMENTARY

by Frederick Gottemoeller



In too many viaducts, the design focus is restricted to the bridge itself. The need to knit back together the spaces under the bridge and relate the bridge to the uses around it is often forgotten. The visual quality and sometimes even the security of the space underneath are ignored. The Presidio Viaduct makes none of those mistakes.

A major goal of the project is to recreate and restore, in so far as it can reasonably be done, the topography and landscape of the Presidio before the Golden Gate Bridge was built, and to make the visible elements of the Golden Gate approach structures as unobtrusive as possible. The aesthetics of this viaduct are really not about the bridge itself; but about what goes on under and around it.

The long spans minimize the number of piers, making it easy to see through the bridge from all angles. The bridge presents little obstacle to the flow of space through it. The piers themselves are simple shapes with no visible pier caps or articulation. The common geometrical shapes tend to fade from our notice.

The curved underside of the post-tensioned concrete box girder is shaped to blend in with the steel braces for the overhangs, visually unifying the parts into one continuous element. The box presents a smooth and featureless underside, with no details that would draw our eye or create visual contrasts. The concrete soffit reflects light into the space under the bridge, keeping the underside spaces bright and supporting the planting. The regularly spaced steel overhang braces establish a rhythm that relates well to the features of nearby buildings, allowing viewers to measure the size of the bridge in comparison to its surroundings. Plus, they create an opportunity to visually tie the viaduct to the Golden Gate by the use of color.

Future users of the Presidio will find it a pleasing structure to be around, one that is an asset to the Golden Gate National Recreational Area.

each span. In span 6, due to traffic clearance limitations, the superstructure depth is reduced to 6.5 ft, decreasing to 4.75 ft at the face of the exterior webs. The columns are rectangular, 8 by 10 ft with the longer faces curved in a 13-ft radius. The viaduct is joined to a 320-ft radius, reinforced concrete connector bridge that leads to Pacific Coast Highway 1. The connector bridge has five spans ranging from 100 to 108 ft in length, with a constant superstructure depth of 6 ft. The connector varies from 33 to 40 ft in width.

Foundation Type

Geological conditions at the site vary drastically along the bridge alignment. The soil strata contain varying depths of sandy/silt layers, along with stiff clay layers underlain by bedrock. The depth to bedrock varies dramatically along the longitudinal alignment of the bridge

The high liquefaction potentials at Bents 3 and 4 dictated the use of pile shafts for the bridge foundations. Historically, these foundation types have performed well in seismic events under similar soil conditions and are superior to spread footings and pile caps as they reduce the possibility of lateral spreading.

Cast-in-drilled-hole shafts with rock sockets were used at all bents. To mitigate the possibility of caving during construction, 12-ft-diameter, permanent steel casings were installed into bedrock at Bents 2, 3, and 4. Additionally, 11.5-ft-diameter rock sockets were installed into bedrock at these bents to a depth of 30 to 40 ft below the permanent steel casing tip elevation.

Seismic Design Considerations

The San Andreas Fault lies approximately 6 miles southwest of the project site and has a maximum moment magnitude of 7.9. The Presidio Viaduct is classified as a post-earthquake "Recovery Route" and as such, seismic design of the viaduct considered two levels of earthquakes, Functional Evaluation Earthquakes (FEE) and Safety Evaluation Earthquakes (SEE). A FEE has a smaller magnitude and a probabilistic hazard for such an event with a mean return period of 108 years (i.e., 50% probability of exceedance in 75 years). A SEE has a greater magnitude with an acceleration response spectrum derived from the envelope of the median deterministic Maximum Credible Earthquake for the region, with a probabilistic hazard for such an event with a mean return period of 1000 years (i.e., 7.5% probability of exceedance in 75 years).

Stiffness Balancing

The drastic variation of the soil profile along the bridge alignment resulted in very stiff columns at Bents 5 and 6 compared to Bents 3 and 4. The related

CAST-IN-PLACE, POST-TENSIONED, CONCRETE BOX GIRDER BRIDGE WITH CAST-IN-PLACE RECTANGULAR COLUMNS AND CAST-IN-DRILLED-HOLE SHAFTS / CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A 1340-ft-long, cast-in-place concrete box girder bridge with variable width and bifurcation. The span lengths are 188, 275, 275, 275, 184, and 143 ft. The section depth is constant at 12.75 ft, except the last span that has a 6.5 ft depth. Cross section has 14-ft overhangs supported by steel fins spaced evenly at about 15 ft centers. The substructure is 8 by 10 ft single or double column bents supported on 12-ft-diameter, cast-in-drilled-hole shafts.

BRIDGE CONSTRUCTION COST: $38.5 million

AWARDS: 2011 ASCE Geotechnical Design Bridge Project of the Year Award, San Francisco, Calif.; 2011 *Roads and Bridges*, Top 10 Bridges in the U.S.

Aesthetic Considerations

Multiple design charrettes were conducted during the planning phase of the project to receive input from stakeholders on design objectives and the preferred type of the new viaduct. The results included these design and architectural criteria:

- Remain subordinate to the Golden Gate Bridge in scale and size
- Maintain continuity by using similar light poles and see-through bridge rails
- Enhance views of the San Francisco Bay by minimizing the number of columns
- Use both concrete and steel materials in construction

Aerial view of the Presidio Viaduct during construction. Doyle Drive is on the right and the Highway 1 Connector Bridge curves to the left.

change in stiffness within the structural frame leads to incoherent seismic performance both longitudinally and transversely.

The project's design criteria required that the stiffness of individual bents within a structural frame vary by less than 50%. In the case of adjacent bents or columns, the variation in stiffness should not exceed 25%. To overcome the variation in bent-column stiffness and achieve uniform seismic performance, two measures were taken:

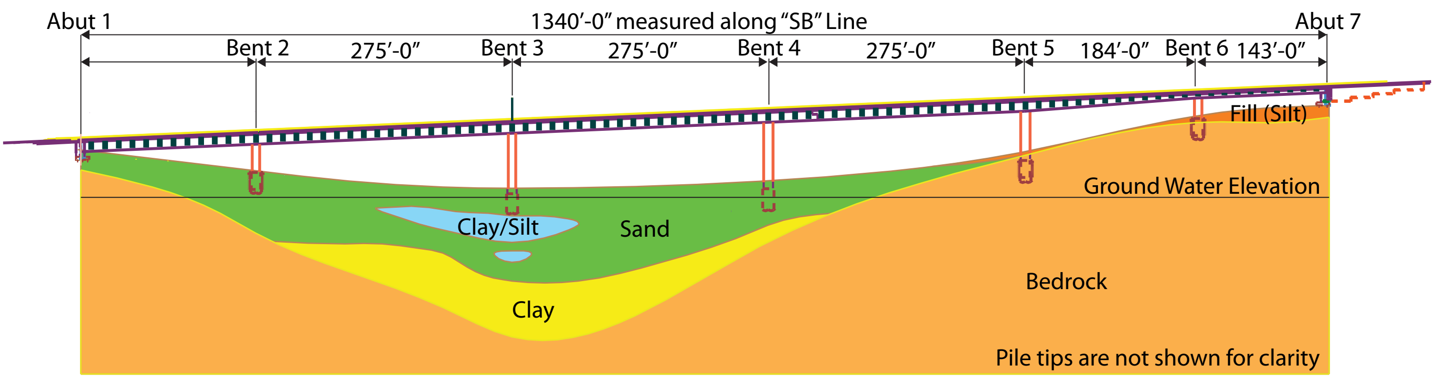
- Column isolation casings were used at Bents 5 and 6 to effectively lengthen individual columns, thereby reducing column stiffness.
- A seismic hinge was used to divide the bridge into three separate structural frames and eliminate pounding during a seismic event. Frame 1 consists of Bents 2 through 4. Frame 2 consists of Bents 5 and 6. Frame 3 consists of the four-bent connector.

Column Reinforcement Configuration

With the soft/loose sandy soil at Bents 3 and 4, displacement demand (obtained from linear response spectrum analysis) at the top of the columns was determined to be 32 in. and 31 in. respectively. Large rectangular columns (8 by 10 ft) do not typically have enough displacement capacity to meet the large demands determined at this bridge. To make up for this, a new column reinforcement configuration was used for this project. Four separate eccentric hoops, with cross ties and headed bars for shear transfer, were used to provide the largest possible plastic deformation capacity for each bent to meet the seismic demands. The specified 28-day concrete compressive strength for the substructure was 5000 psi.

Superstructure

As described earlier, the bridge is designed as three structural frames. Frame 1 is much wider and consists of spans 1 through 3. It has a three-cell box girder cross section. Frame 2—spans 4 through 6—consists of a two-cell box girder. Frame 3 is the Highway 1 Connector Bridge that has five spans with a three-cell box girder with a shallower cross section. Frames 1 and 2 have a deck overhang of 14 ft. The overhangs on all three frames are supported by a combination of steel fin outriggers and post-tensioning. The steel fins were initially conceived to meet aesthetic goals and later incorporated into the structural design of the overhangs. Transverse post-tensioning in the deck used three or four 0.6-in.-diameter, 7-wire strands in



Presidio Viaduct soil profile.

Unique reinforcement arrangement for the 8 by 10 ft rectangular columns.

1 by 3 in. flat ducts spaced from 2.5 to 4 ft. The jacking force varied from 131 to 175 kips. The structural steel fins were integrated with the formwork and cast monolithically into the cross section. The 256 fins are spaced uniformly approximately every 15 ft along each span.

Due to long span lengths, considerable prestressing was required in both frames 1 and 2. In addition to full length post-tensioning, partial length post-tensioning was required to achieve the desired performance. Frame 1 has four webs with six post-tensioning ducts. Frame 2 has three webs with six post-tensioning ducts. The ducts have diameters of either 4 or 4½ in. and contain 19 or 25 Grade 270, 7-wire, low-relaxation strands with a diameter of 0.6 in. The total number of strands in Frames 1 and 2 is 551 and 412, respectively. The corresponding jacking forces are 24,200 kips and 18,100 kips. The frame lengths required that the stressing be done from both ends.

The specified concrete for the superstructure was Caltran's typical ternary mix that required supplemental cementitious materials in combination with portland cement to assure longevity. The specified compressive strength for the superstructure was 5000 psi at 28 days.

Construction Challenges

Of primary concern was the construction of the large diameter deep drilled shafts through poor soil conditions. The permanent steel casings reduced the potential for delays resulting from repairs of anomalies in the drilled shafts. However, repairs due to caving were required during the construction of the rock socket at Bent 2.

The majority of falsework erected was of the standard type used in California. However, 10 precast, prestressed concrete girders, each 108 ft long, were used to span the culturally sensitive Presidio Pet Cemetery underneath the Presidio Viaduct. These precast girders provided a platform on which superstructure-supporting falsework bents, typically made of steel pipe posts with W section cap and sill beams, could be erected.

Throughout the construction of the project it was critical to work with all stakeholders in order to minimize impacts to the operations, structures, and environment of the Presidio of San Francisco and the Golden Gate National Recreation Area. The Presidio Viaduct is an engineering feat that surmounted complex site conditions and will complement the unique surroundings of an urban national park.

Ahmed M. M. Ibrahim is senior bridge engineer, John F. Walters is senior bridge engineer and construction engineer, and Ofelia P. Alcantara is supervising bridge engineer, all with the California Department of Transportation in Sacramento, Calif.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

The steel fins that support the 14-ft-long cantilevers are shown in the structure and in place during construction of the concrete formwork.

Placing concrete in the soffit of the box girder.

Precast, prestressed concrete girders were used to span the culturally sensitive Presidio Pet Cemetery and support the falsework bents.