

## Historic Category

# Repair of Cabrillo Bridge in Balboa Park

San Diego, California

Submitted by BASF Building Systems

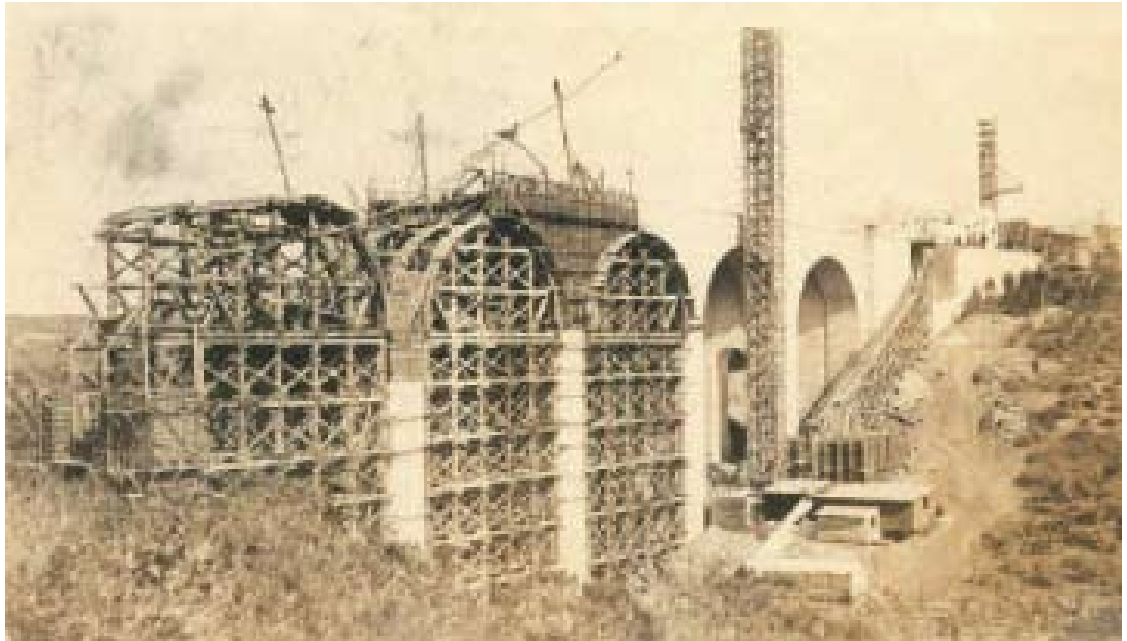


Fig. 1: Bridge during original construction

The Cabrillo Bridge is one of the most historic bridges in all of California. The bridge, which passes over California Highway 163 in San Diego's Balboa Park, has the architectural appearance of seven closed-spandrel cast-in-place reinforced concrete arches and mimics the Spanish-Colonial style (refer to Fig. 1). Structurally, however, the bridge is not a series of continuous arches; rather, it is composed of hollow vertical sections with cantilevered box girders that form the arched openings. The concrete walls are 6 to 24 in. (15 to 61 cm) thick and made with board formed concrete. The original formwork from 1915 is still in place inside the columns.

The original bridge was designed to be an eye-catching, majestic structure that would attract the world's travelers to the city's 1915 exposition. Inspired by the graceful lines of Spain's Tajo Bridge, designer Thomas B. Hunter of San Francisco came up with a massive, cantilevered edifice to span what was then a lagoon in a canyon at the park's edge. Later, the state highway was built underneath.

The bridge was completed in 1914 at the cost of \$196,000, including design and supervision, for the Panama-California Exposition in San Diego. On April 12, 1914, future President Franklin Roosevelt was driven in the first automobile across the towering span while serving as Secretary of the Navy.

The most detailed description of the structure of the Cabrillo Bridge was published in *Engineering News*, May 13, 1915. Quoting from *Engineering News*, Cabrillo Bridge is a concrete and steel bridge consisting of seven "hollow, box-like pedestals with the upper part cantilevering out to form arched openings. The bridge, including its approaches, is 916 ft (279 m) long. Its main 450 ft (137 m) long portion comprises seven semicircular 56 ft (17 m) arches, with a maximum height of 120 ft (37 m) to the roadway."

To relieve stress and to carry a uniform load of 100 pounds per square inch (690 kPa), the roadway cantilevers were set in reinforced concrete columns. As the stress on sidewalk arcades was not as severe, sidewalk cantilevers did not need such reinforcement.

Concrete curtain walls, covering and connecting the columns, extended to the level of the roadway. The roadway under the bridge was an extension of 11th Street to the north end of the park that passed through the third of its seven arches on the eastern side.

The span was entered on the National Register of Historic Places in 1976. Due to this fact, the California Department of Transportation (Caltrans) had to hire on-site historical preservationists and a specialized structural engineer as consultants on the project. The bridge is currently the active entrance to Balboa Park and the San Diego Zoo.

## Problems that Prompted Repair

Chunks of original concrete from beneath the arches had become dislodged and fallen to the ground. Concerns about safety and potential structural performance problems prompted an investigation to be done in connection with bridge repairs being performed by the contractor and Caltrans.

## Inspection/Evaluation Methods

A consulting structural engineer was engaged to assess the bridge concrete's quality, condition, and future durability potential to help Caltrans and the contractor develop repair and maintenance strategies. The firm reviewed bridge drawings and background information; visually reviewed the bridge pier conditions in accessible areas; documented observations with notes, sketches, and photographs; hammer-sounded elevations based on observed conditions to identify possible delamination; performed field carbonation tests at selected core locations to evaluate depth of concrete carbonation; and removed core samples for laboratory testing.

## Test Results

Inspection and test results showed the primary cause of concrete spalling and delamination to be corrosion of embedded steel reinforcement. Factors contributing to steel corrosion over the bridge's service life included concrete carbonation, available moisture sources, and depth of concrete cover over reinforcing steel; general concrete quality; and chloride levels.

The consulting structural engineer found that the bridge pier vertical elevation concrete was capable of providing the embedded steel reinforcement adequate protection against corrosion where the concrete is well consolidated. Concrete at the cantilevered arch elevation was carbonated at the reinforcement level in many areas. Corrosion was deemed likely to continue in these regions, but more slowly as planned repairs prevent moisture from entering the bridge interior.

The consulting structural engineer's report described how the concrete's durability potential could be enhanced through further repairs, such as shotcrete or form-and-pour patches, or alternative repairs involving sacrificial anodes, penetrating



*Fig. 2: The entire underside had a very extensive scaffolding system*

corrosion inhibitors, impressed current cathodic protection, or concrete realkalization, included in an ongoing repair and maintenance program.

## Repair System

Spalls were first prepped, formed, and then repaired with a one-component, shrinkage-compensated micro concrete. Prior to placement of the forms, the reinforcing steel was coated with a one-component epoxy primer designed to prime and protect reinforcing steel. The reinforcing steel primer combats corrosion through electro-chemical means by preventing anode transfer.

After forms were removed, a low-slump, fast-setting, portland-cement-based, multi-purpose smooth repair mortar was used to recreate the original concrete texture, color, and appearance. The material did not require the use of forms or multi-layered casting techniques.

## Surface Preparation

ICRI Technical Guideline No. 03730, "Guideline for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion," was followed. This included the following steps:

- Sawcut perimeter of area;
- Chip with 25-lb and smaller chipping hammers, followed by sandblasting and waterblasting;
- Make required minimum 1 in. (2.5 cm) to full depth through the wall repairs;
- Wash, which couldn't remove the 90-year-old patina; and
- Coat cleaned reinforcing steel (refer to Fig. 3).

## Application Methods and Repair Process Execution

New stainless steel reinforcing and wires were then installed.

One to 2 in. (2.5 to 5.1 cm) repairs were placed in by hand to match the board formed appearance

Fig. 3: Cleaned reinforcing steel was coated



Fig. 4: Deeper repairs held low by 1 in. (2.5 cm) to the surface



Fig. 5: Use of smooth repair mortar to complete repair. Note recreation of form lines



using color-matched low-slump, fast-setting, portland-cement-based, multi-purpose smooth repair mortar. Part of this process was the recreation of the form lines from original construction.

Deeper repairs to full depth were first formed and poured using one-component, shrinkage-compensated micro concrete. The forming was held low by 1 in. (2.5 cm) to the surface. Low-slump, fast-setting, portland-cement-based, multi-purpose smooth repair was hand applied to complete the repair (refer to Fig. 4).

Low-slump, fast-setting, portland-cement-based, multi-purpose smooth repair was hand applied to complete the repair (refer to Fig. 5).

## Unforeseen Conditions Found

- After vines were removed, the need for significantly more repair work was noted. The contract value jumped up from \$1.5 million to roughly \$3.5 million. "Once we were able to strip all the ivy off and get up close to it, I think there is more (damage) than anybody originally anticipated," said Bill Morgan, the Caltrans engineer overseeing the project;
- Labor intensity that was required to replicate the board formed surface;
- Color matching the repair mortar to original color;
- Maintaining the correct water-cement ratio (*w/c*) of the repair material to maintain a consistent color match;
- Arson fire of the original form boards inside the structure columns created a major cleaning effort during the project. Cleaning efforts had to take care not to scrub off the 90-year-old patina; and
- While at work, laborers discovered a broken drainage system within the bridge that may have contributed to the steel corrosion. A water line for fire hydrants was also found leaking.



Fig. 6: The Cabrillo Bridge with all historical restoration work complete. Note it does not appear "patched"

## Cabrillo Bridge

### Owner

State of California  
Department of Transportation  
Sacramento, California

### Project Engineer/Designer

CK Arts  
Bel Air, California

### Repair Contractor

Erreca's, Inc.  
Deer Park, Texas

### Material Supplier/Manufacturer

BASF Building Systems  
Shakopee, Minnesota