Cable Supported Bridges

Concept and Design

Second Edition

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Bridge, the Ohshima Bridge, the Askøy Bridge, the Great Belt East Bridge, the Högakusten Bridge and the Kurushima Bridges — all based on the streamlined box girder concept — have been build with vertical hangers.

The reason for this reversal was that aerodynamic studies proved that the required stability could actually be achieved without the inclined hangers, and also that fatigue problems were experienced in the Severn Bridge hangers due to the stress variations occurring under passing traffic.

Earlier it had also been proposed to make the connection between the girder and the cable as a net of intersecting cables, improving the ability to transfer shear forces between the main cable and the girder (Figure 3.60). With a continuous stiffening girder able to transfer axial forces at the pylon this system can to some extent act as a double cantilever truss.

In the mono-cable bridge proposed by F. Leonhardt around 1960 the single main cable was connected to the girder by two inclined hanger nets, as is seen in Figure 3.61. Through the application of a triangular cross-section consisting of the roadway slab and the two hanger nets a high degree of torsional resistance was achieved, so it should be possible to use a very slender girder without any noticeable torsional rigidity. In the proposed system the combination of a single main cable and skew hanger nets made it necessary to keep the cable a certain distance above the roadway at midspan. With a given main cable sag this will require increased pylon heights and steeper side span cables. Furthermore, the system with a hanger net as shown in Figure 3.60 will inevitably complicate the erection procedure compared to systems with vertical hangers only.

All major suspension bridges are built with an earth anchored system where the force of the main cable is transferred to the soil through anchor
blocks at the ends of the side spans. However, in some small-to-medium sized suspension bridges the self anchored system illustrated in Figure 3.62 has been applied. At first glance it might look very promising to get rid of the large (and often quite clumsy) anchor blocks, but taking into account that the compression in the stiffening girder requires a larger cross-section (leading to increased girder dead load) and that during erection the main cable cannot carry any load until the stiffening girder is in place, makes the self anchored system less attractive.

A number of self anchored suspension bridges were constructed in Europe before World War II but in the postwar period it became evident that the complications during construction made the self anchored suspension system inferior to either the earth anchored suspension system or the self anchored cable-stayed system.

A unique example on a recent self anchored suspension bridge is the Konohana Bridge in Japan (Figure 3.63). This bridge is not only unusual due to its self anchored suspension system but also by having only one central main cable — as in the original proposal by F. Leonhardt (refer to Figure 3.61). However, Leonhardt introduced the concept primarily to increase the torsional stiffness of long span, earth anchored suspension bridges, and to achieve this the main cable and the bridge girder were to be connected by two inclined hanger nets attached along the edges of the stiffening girder. In the Konohana Bridge the single main cable is connected to the girder through only one vertical hanger plane.
so that no additional torsional restraint was achieved by the mono-cable arrangement.

The drawbacks of the self anchored suspension system was to some extent demonstrated during construction of the Konohana Bridge as the bridge girder had to be supported by a total of 7 piers (4 permanent and 3 temporary) until the cable system could be erected. In case of a self anchored cable-stayed bridge the erection could have been carried out without any temporary supports.

It is therefore not to be expected that the Konohana Bridge, despite its pleasing appearance, will be followed by other self anchored suspension bridges with a central cable plane.

### 3.2 FAN SYSTEM

Within cable-stayed bridges the fan system has become the favourite cable system due to its efficiency and the degree of freedom regarding geometrical adaption.

In recent times the fan system is most commonly applied in the form of a modified fan system where the cable anchor points are spread over a certain height $h_{an}$ at the pylon top (Figure 3.64 to the left) to give room for an individual anchoring of each stay cable.

In the common cases where the anchor zone at the pylon top is extended over a relatively short distance the behaviour of a bridge with a modified fan system and a pure fan will be very similar. Consequently, the preliminary analyses can be based on a system with a pure fan system and in this case the cable anchor point in the pylon should be chosen to have a position at the upper third of the actual anchor zone as indicated in Figure 3.64 to the right.

![Fig. 3.64 Anchoring of stay cables in a modified fan (left) and an equivalent pure fan (right) for preliminary calculations](image-url)
APPENDIX J

Selected Newspaper Articles
Realigning span could hike costs

By Lisa Vorderbrueggen
Times Staff Writer

Realigning the new Bay Bridge to satisfy San Francisco Mayor Willie Brown and the Navy would delay the project at least eight to 15 months and add tens of millions of dollars to the cost, a White House-ordered report concludes.

Caltrans officials said the findings bolster its position. The state has spent $70 million on environmental, engineering and design work for a new eastern span north of the existing bridge.

"We expected this, of course, but it is good news to have your work backed up by an outside party," said Caltrans spokesman Greg Bayol.

After being lobbied by Brown and Gov. Gray Davis to intervene, the White House in August asked the Army Corps of Engineers to evaluate the contradictory alignment.

See SPAN, Back Page

Span

FROM PAGE 1

analyses by Caltrans and San Francisco.

The California Department of Transportation determined it would cost more money and time to switch to a southern route, while San Francisco's hired engineers said it could be done as fast and for less money.

He confirmed Caltrans' findings, said corps' spokesman Doug McRitten in San Francisco.

But Annemarie Conroy, Brown's redevelopment project director, said the report is not the clear blow it appears to be. It confirms that Caltrans has done sloppy work on bridge plans, she said.

The environmental document for the northern alignment, she said, "will be dead on arrival" because it is flawed, and the city intends to challenge it in court:

Caltrans officials never seriously looked at the possible southern alignment for the Bay Bridge, and if they had, "they wouldn't be looking at delays and extra costs ..., if money has been wasted, Caltrans has wasted it."

Caltrans spent $70 million on plans knowing it would never get permission from the Navy and San Francisco, Conroy said.

A northern span will devastate San Francisco's plans for Yerba Buena Island, threaten historic buildings and cost San Francisco and the Navy tens of millions of dollars in lost revenue.

The city wants to build restaurants, a hotel or conference center, and live-work lofts in the shoreline region that is needed for the northern alignment. Historic buildings on the site, including the Nimetz Machine and a torpedo factory, would be reused under the city's plan. The Navy would get a share of revenue for 15 years.

Navy spokesman Jeff Young said the alignment dilemma is being discussed at the "highest levels" in Washington.

"This is a difficult situation for the Navy," Young said. "If the Navy caves into the northern alignment, it will violate state and federal law as it pertains to protecting historic resources and (renew) on a deal it made with San Francisco."

On the other hand, Young says the Navy wants a solution to the hazards posed by an earthquake because "our families drive on the bridge, too."

The stance of San Francisco and the Navy is drawing increasing fire from California officials who look at the Bay Bridge and see a seismic time bomb. The U.S. Geological Survey says there is a 70 percent chance of a major earthquake in the Bay Area within 30 years.

"If an earthquake hits, the bolts will shear and that bridge will come down, and people will die, all because San Francisco is worried about whether it can lease space for a brew pub," said Mark DeSaulnier, Contra Costa County supervisor and member of the Metropolitan Transportation Commission.

"I thought it was the Navy's position to protect citizens, not put them at risk," DeSaulnier said. "This situation is criminal and irresponsible."

California Transportation Commission member Jeremiah Hallisey of Alamo is demanding the Navy appear at the commission's Feb. 23 meeting in Los Angeles and explain what he called its "disgraceful position."

"Every day that we delay is putting several million people at physical and economic risk," Hallisey said.

It was 1989 when the Loma Prieta earthquake struck the Bay Area, knocking off a 50-foot section of the eastern Bay Bridge's upper deck. One motorist died.

Seismic experts said the now 64-year-old bridge cannot withstand another major quake.

It took 10 years for the state to select a new suspension span, with a 600-foot tower on the Yerba Buena side and a viaduct curving toward Oakland.

Construction was supposed to have started this year but was delayed for months in 1999 after the Navy refused access to Yerba Buena Island for drilling.

Caltrans and the Federal Highway Administration hope to release the...
Bay Bridge battleground

An Army Corps of Engineers study finds that switching to a southern route for the Bay Bridge would delay construction eight to 15 months and would cost tens of millions of dollars more than a northern span. San Francisco Mayor Willie Brown and the Navy oppose the northern alignment.

Task Force, Davis, Caltrans and the California Transportation Commission all say a new, northern span is the best option.

A retrofit cannot guarantee the bridge — considered a lifeline route — will remain passable during an earthquake. It also will not allow for a pedestrian and bicycle lane, which is included in the new span's design.

The Caltrans Seismic Advisory Board said in September that a retrofit of this magnitude has never been attempted and would result in "significant uncertainties in its seismic performance at a cost which would nearly equal that of a new bridge."

A southern alignment, say the Army and Caltrans, is fraught with extra costs and potential delays.

"Switching the alignment would add at least $75 million to $150 million just for added environmental work and the cost of delays due to inflation," said Steve Heminger, deputy executive director for the Metropolitan Transportation Commission. "It is time to stop flying back and forth to Washington and sit down at the table, discuss mitigation and compensation for the Navy and San Francisco and cut a deal."

Lisa Vorderbrueggen covers transportation and growth. Reach her at 925-228-6179 or lvorderbrueggen@cctimes.com.
Davis tries to break Bay Bridge standoff

Tyra Hendricks  
OF THE EXAMINER STAFF

Governor asks for federal intervention to resolve logjam on replacement span

Faced with a standoff over rebuilding the earthquake-vulnerable eastern span of the Bay Bridge, Gov. Davis has turned to the federal government for help.

Davis, in Washington, D.C., for the National Governors' Association meeting, told reporters he spoke to President Clinton on Tuesday morning about bringing in the Army Corps of Engineers to move the seismic work on the Bay Bridge forward.

"We're making progress. I would expect we could start on the 'northern alignment' this year," Davis said, referring to a proposed replacement span that would run to the north of the current bridge.

The project has been stalled for months by a standoff between Caltrans, the state's transportation agency, which is charged with rebuilding the bridge, and the U.S. Navy, which owns Yerba Buena Island, where the east span anchors. The Navy opposes the proposed northern alignment favored by Caltrans.

Before quake hits

A segment of the truss bridge from Oakland to Yerba Buena Island collapsed in the 1989 Loma Prieta earthquake, and all sides agree seismic improvements are needed before another quake hits.

Caltrans has spent an estimated $70 million on design and testing for the proposed northern alignment. But the Navy and city of San Francisco, which also opposes the northern span, say it could jeopardize historic buildings and The City's economic development options for re-using the Treasure Island Naval Base.

http://www.sfgate.com/cgi-bin/article.cgi?file=/examiner/archive/2000/03/01/NEWS149.dtl 3/3/00
"It's a logjam," said Caltrans spokesman Jeff Weiss. "The Navy is a higher agency and we can't condemn Navy land and they're saying no. We believe the Army Corps of Engineers is being brought in to break the logjam and to make an independent analysis of all the alternatives."

Navy spokesman Jeff Young said the Navy is eager to see the situation resolved, but remains adamantly opposed to the northern option.

"The easiest way to resolve the issue is to use an option other than the northern alignment," he said. "Had Caltrans done that to begin with, prior to spending $70 million on an option that's doomed to failure, the bridge would be under construction by now."

Range of options

Young added that Caltrans was obligated in the environmental review process to give equal consideration to a range of options, including a southern alignment and a retrofit of the existing bridge. He believes the state agency failed to do that, selecting the northern route without considering the alternatives.

Davis's comments Tuesday suggested that he too was discarding the southern route proposed by San Francisco officials as an alternative.

"We're really talking about an April review (by the Army Corps) looking at the seismic and engineering assumptions that are underlying both the retrofit proposal and the northern alignment proposal," he said. "All the environmental review would be complete in calendar 2000."

Army Corps spokesman Gary Britter, in Sacramento, confirmed that his agency had been asked to participate as a third party in a limited engineering analysis.

"The proposal has been sent to headquarters in Washington for review," he said. "They haven't gotten back to us yet."
Mayor Willie Brown was unreachable Tuesday.
His press sec

tetary Kandace Bender said, "It would be
inappropriate for me to speculate on the
governor's comments because we don't know the
context."

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Examiner Sections 33 33
APPENDIX K

Bay Bridge Design Task Force / Engineering and Design Advisory Panel  
Meeting Schedule
<table>
<thead>
<tr>
<th>Event Type</th>
<th>Date/Location</th>
<th>Time</th>
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<tr>
<td>Open House</td>
<td>Monday, December 8, 1997, San Francisco</td>
<td>1:00 p.m.</td>
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<tr>
<td>Open House</td>
<td>Tuesday, December 9, 1997, Walnut Creek</td>
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<td>Thursday, December 11, 1997, Oakland</td>
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<td>May 12-14, 1997</td>
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<td>Tuesday, July 6, 1999</td>
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APPENDIX L

References
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