Engineering the Golden Gate

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Engineering the Golden Gate
The Interplay of Design and Experience

1. Origins of the Long-Span Bridge
2. Balancing Forces: Cables and Deck
3. Earth to Sky: Foundations and Towers
4. Standing in Motion: Aerodynamics and Earthquakes
5. The Color of Endurance: Maintaining the Bridge
6. The People and their Bridge
The Golden Gate

Looking west toward the Pacific Ocean in 1902
Elastic Theory

Steinman Estimates 1922
Max. Practicable Span = 5000 feet
Max. Economical Span = 3200 feet
Span / Depth = 40:1

Golden Gate main span minimum length = 4000 feet
Enter Joseph Strauss

Joseph B. Strauss (1870-1938)

Original Strauss design (1921)
From Elastic to Deflection Theory

Williamsburg Bridge (1903)  
*Elastic Theory*

Manhattan Bridge (1909)  
*Deflection Theory*
Creating the Golden Gate Bridge

Board of Engineers

*From left:* Leon Moisseiff, Joseph Strauss, Othmar Ammann, Charles Derleth Jr.
### Deck and Truss

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Main Span</th>
<th>Span / Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delaware</td>
<td>1750 feet</td>
<td>63 : 1</td>
</tr>
<tr>
<td>Geo. Washington</td>
<td>3500 feet</td>
<td>120 : 1</td>
</tr>
<tr>
<td>Golden Gate</td>
<td>4200 feet</td>
<td>168 : 1</td>
</tr>
</tbody>
</table>

Main Span is given in feet and depth in meters.
Towers and Cables

Golden Gate Bridge
- Towers: 746 feet (228 m)
- Cable Sag: 475 feet (145 m)

George Washington Bridge
- Towers: 604 feet (184 m)
- Cable Sag: 316 feet (96 m)
Towers: Design

- Stepped shafts
- Portal struts above deck, diagonals below
- Cellular design

Diagram showing different sections of towers with dimensions and weights for Golden Gate, George Washington, San Francisco-Oakland, and Philadelphia-Camden bridges.
Towers: Model Testing

Golden Gate Bridge Tower Model
1:56 Scale

Testing Frame at Princeton, 1938
Towers: Model Testing

Golden Gate Bridge Tower Model
1:56 Scale

Testing Frame at Princeton, 1938
Three Bridges: Aesthetics

St. John’s Bridge (1931)

Golden Gate Bridge (1937)

Bronx-Whitestone Bridge (1939)
Aerodynamic Risk

Golden Gate, 1937
168:1

Deer Isle, 1939
166:1

Bronx-Whitestone, 1939
210:1

Tacoma Narrows, 1940
350:1
Aerodynamic Risk
Aerodynamic Risk

Tacoma Narrows Bridge failure
November 7, 1940
Back to the Future

Brooklyn Bridge with stays

Bronx-Whitestone Bridge with stays and added truss
University of Washington
Aerodynamic Stability Tests
1940s

Lower lateral bracing added 1953-54
Roadway Replacement 1982-85

Cross-section of orthotropic deck

Installing deck
Roadway Replacement

People on bridge for 50th anniversary 1987
Loma Prieta Earthquake

October 17, 1989
05:04:15 PM Local Time

Magnitude 6.9

Cypress Freeway collapse
(H.G. Wilshire, U.S. Geological Survey)

San Francisco-Oakland Bay Bridge
[C.E. Meyer, U.S. Geological Survey]
Seismic Retrofit Program

- Install energy dissipation devices
- Replace expansion joints
- Anchor pylons to bedrock
- New steel supports for viaducts
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Golden Gate Bridge 75 Years

Achievements
- Met traffic demand
- Met financial needs
- Still standing
- Iconic bridge

Future Questions
- Seismic event (“The Big One”)
- Environmental change
- Lifespan of structure
- Would the same bridge be rebuilt?
We would like to thank:

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  GGBHTD

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  CUREE

• Mary Currie, director of public affairs
  GGBHTD