The Brooklyn Bridge

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Bridge Failures

1986 Loma Prieta

1994 Northridge

1995 Kobe

1986 Loma Prieta

1986 Loma Prieta

1995 Kobe
Educational and Research Programs in Earthquake Engineering

Hayes *Earthquake Engineering Center* and *Seismic Recording Station*

- Shaking Table
- Seismic Recording Station
- Earthquake Damage Investigations
The Brooklyn Bridge
“The Great East River Bridge”
Built in 1883

Seismic Safety Assessment
And Retrofitting
Anonymous photograph of
John A. Roebling (1806-1869),
aged 90
Collection: Rutgers University,
New Jersey

Left: Anonymous photograph of
Washington A. Roebling (1837-1926),
circa 1870
Collection: Rutgers University, New Jersey

Right: Anonymous photograph of Emily Warren Roebling (1843-1903), circa 1880
Collection: Rutgers University, New Jersey
Chronology

1802  Petition by citizens of Manhattan for a bridge.

1857  John Roebling pronounces a suspension bridge to be “feasible and within the cost of a profitable invention”.

1865  John Roebling prepares plans for his Bridge.

1866  New York State Legislature provides funds for the Bridge.

1867  New York Bridge Company is incorporated with John Roebling as Chief Engineer.

1869 (June 20)

President Ulysses S. Grant signs bill approving the plan and location of the Bridge.

1869 (June 21)

John Roebling dies in an accident by the East River while determining the location of the Bridge.

His son, Col. Washington Roebling is appointed Chief Engineer.
1870  Construction of the Bridge begins.
1871  Washington Roebling and six men suffer “Caisson Disease”.
1872  Washington Roebling becomes an invalid and directs the construction crew from his window and with the help of his wife Emily.
1874 -
1882  Construction proceeds with scandals, financial troubles and delays
1883 (May 24)
   The Brooklyn Bridge is opened and dedicated
1883 (May 30)
   Decoration Day, 10,000 sightseers are on the Bridge. A woman falls, people panic and the stampede kills 12 people.
A Few Statistics

• 27 workers and 12 sightseers died.
• Construction took 15 years, 3 times longer than John Roebling’s estimate.
• Total cost was 16 Million Dollars, twice the original cost estimate.
William Vanderback
Boreholes for the Foundation of the
Brooklyn Bridge (1869)
Black ink, colored ink, and watercolor on
tissue
55.9 x 44.4 cm, (22 x
deep)
Collection: Municipal
Archives of the City of
New York, neg. 2012
Photo courtesy: American
Architects and
Planning Library

Boreholes for the tower foundations right and
facing page revealed that the foundation at the
Brooklyn side would be closer to the surface on the
Brooklyn side than on the
New York side, meaning the New York
foundation would have to be placed at a
greater depth.
Washington Roebling
was forced to
abandon this original
plan, however, when
three men experienced
fatal falls from the
rocks due to
extraction disease during
the excavation on the
New York side. He decided
that the Brooklyn
tower would be on a
comparatively
deep foundation of gravel
and sand instead of going
deeper to find bedrock.

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Fig. 8.—New York and Brooklyn Anchorages
Manhattan Cable Anchorage  

Brooklyn Cable Anchorage

- 4-ft Timber Mat
- Soil
- Granite Blocks
The work on the Bridge was organized so that both the anchorage structures and the towers would be completed at once. Only when the anchorages were complete, ready to secure the cables and resist their tremendous pull, could cable spinning begin. The anchorage system John Roebling had devised in his earlier bridges was used here on a larger scale. Four 23-ton iron anchor plates, one for each of the four cables, were positioned at the bottom of both anchorages. Eighteen 12-foot-long eyebars radiated from the center of each plate, forming the first link in a double-tiered eyebar chain extending to the top of the anchorage. As the successive links of the chain were attached to each other they were encased in masonry. At the top, the number of eyebars in the last link of the chain was increased to thirty-eight, and each of the nineteen strands of wire that made up each cable was pinned between a pair of eyebars.
2500-year Earthquake
Manhattan Approach-North Side

Manhattan Approach-South Side

Legend:
1. Fill
2. Organic silt and clay
3. Sand
4. Gravel/Cobbles (Till)
5. Bedrock (Mica Schist)

Note:
- B-1 to B-14, URS (2004-2005)
- Other boreholes from MRCE 1996 report
Approach Footings

18'

5.5'

Street

B

Cellar

10'

CL
Foundation Stability

Street

18'

5.5'

10'

bearing

sliding

lift-off

F_v

F_H

B

Foundation Stability

Street

18'

5.5'

10'

bearing

sliding

lift-off

F_v

F_H

B
Manhattan Cable Anchorage:
3-D Model and Site Characterization

Brooklyn Bridge
Manhattan Cable Anchorage
Foundation and Soil Profile

1: \( V_s \) = Shear Wave Velocity
2: \( V_p \) = Compressional Wave Velocity

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>( V_s ) (ft/s)</th>
<th>( V_p ) (ft/s)</th>
<th>Layer Description</th>
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<tbody>
<tr>
<td>0</td>
<td>810</td>
<td>2370</td>
<td>Fill</td>
</tr>
<tr>
<td>5'</td>
<td>750</td>
<td>2370</td>
<td>Fill</td>
</tr>
<tr>
<td>10'</td>
<td>710</td>
<td>5000</td>
<td>Sand and Gravel</td>
</tr>
<tr>
<td>14'</td>
<td>930</td>
<td>5000</td>
<td>Sand and Gravel</td>
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<td>25'</td>
<td>1030</td>
<td>5000</td>
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<td>1140</td>
<td>5000</td>
<td>Sand and Gravel</td>
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<tr>
<td>55'</td>
<td>1250</td>
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<td>Sand and Gravel</td>
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<tr>
<td>120'</td>
<td>3000</td>
<td>5000</td>
<td>Gravel/Cobbles/Boulders</td>
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</table>
Manhattan Cable Anchorage: Computed Motions

- Brooklyn Bridge
- Manhattan Cable Anchorage
- E1, 2500-year Event
- Foundation Base Motions

Revised 10-1-05
Manhattan Caisson: Foundation Stiffness

Sliding or Gapping Permitted
Manhattan Caisson: Foundation Stiffness

Sliding or Gapping Permitted
Brooklyn Caisson: Foundation Stiffness

Sliding or Gapping Permitted

Longitudinal Section
Seismic Analysis

Tower-Caisson-Soil

effective normal stresses
shear stresses
gapping or sliding
caisson internal stresses
bearing pressure
Manhattan Tower
Seismic Analysis
Transverse Direction
E1, 2500-year Event

Accelerations

- 0.51g
- 0.32g
- 0.21g
- 0.35g
- 0.31g
- 0.26g
- 0.35g

Baserock
Manhattan Tower
Seismic Analysis
Longitudinal Direction
E1, 2500-year Event

Interface Vertical Displacements
Due to Horizontal and Vertical Motions

[Graph showing vertical displacements at the top and bottom of the interface over time]
Baserock

Manhattan Tower
Seismic Analysis
Longitudinal Direction
E1, 2500-year Event

Tower and Caisson Shear Stresses

Deck Level Shear Stresses
Along Section A-A

Initial  Maximum  Minimum

Timber Grillage Shear Stresses
Along Section B-B

Initial  Maximum  Minimum

Concrete Shear Stresses
Along Section C-C

Initial  Maximum  Minimum
Manhattan Tower
Seismic Analysis
Longitudinal Direction
E1, 2500-year Event

Caisson Base-Shear and Normal Stresses
Due to Horizontal and Vertical Motions

Baserock
Manhattan Tower
Seismic Analysis
Transverse Direction
E1, 2500-year Event

Caisson Base-Shear and Effective Normal Stresses
Due to Horizontal and Vertical Motions
Conclusions:
1- The Main Bridge is safe against 2500-year earthquake.
2- Many of the approach span footings need to be retrofitted.