Seismic Design of Long-Span Bridges

by

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Cape Girardeau, Missouri

What makes a long-span bridge long?

- Type of Bridge
  - Prestressed Concrete Girders
  - Steel Plate Girders and Box Girders
  - Grade Separations
  - Interchanges

Generally DO NOT qualify

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What makes a long-span bridge long?

- AASHTO

Primarily, the specifications set forth minimum requirements which are consistent with current practice, and certain modifications may be necessary to suit local conditions. They apply to ordinary highway bridges and supplemental specifications may be required for unusual types and for bridges with spans longer than 500 feet.

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What makes a long-span bridge long?

- AASHTO Division IA

The provisions apply to bridges of conventional steel and concrete girder and box girder construction with spans not exceeding 500 feet (150 meters). Suspension bridges, cable-stayed bridges, arch type and movable bridges are not covered by these Specifications. Seismic design is usually not required for buried type (culvert) bridges.

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- Four Methods of Analysis
  - Uniform Load Method
  - Single Mode Spectral Analysis
  - Multimode Spectral Analysis
  - Time History Method

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TABLE 4.2A Minimum Analysis Requirements

Seismic Performance Category	Regular Bridges with 2 Through 6 Spans	Not Regular Bridges with 2 or More Spans
A	Not required	Not required
B, C, D	Use Procedure 1 or 2	Use Procedure 3

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TABLE 4.2B Regular Bridge Requirements

Parameter	Value				
Number of Spans	2	3	4	5	6
Maximum subtended angle (curved bridge)	90°	90°	90°	90°	90°
Maximum span length ratio from span-to-span	3	2	2	1.5	1.5
Maximum bent/pier stiffness ratio from span-to-span (excluding abutments)	—	4	4	3	2

Note: All ratios expressed in terms of the smaller value.

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What makes a long-span bridge long?

- AASHTO
  - Spans in excess of 500 feet
  - Arch Bridges
  - Suspension Bridges
  - Cable-stayed Bridges
  - Major Truss Bridges

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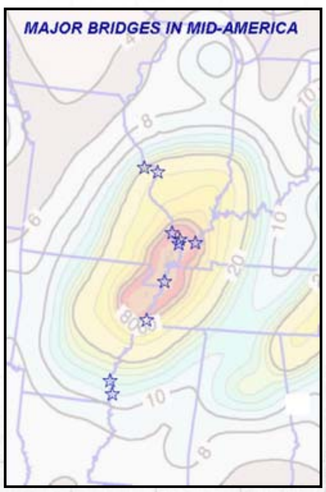
What makes a long-span bridge long?



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- Time History Method
  - 5 spectrum-compatible time histories
  - Derived from a site-specific spectrum
  - Evaluate the sensitivity of the analysis to:
    - Time increment
    - Variations in materials
- We add to that
  - Effects of spatial incoherency
  - Effects of liquefaction

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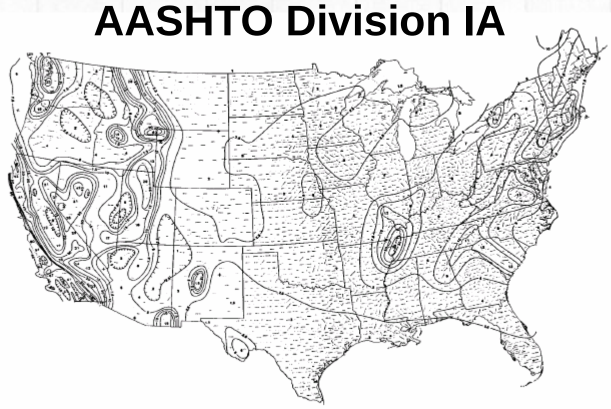

10% Probability of Exceedance in 50 Years
475-Year Return Period

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Bill Emerson Memorial Bridge

- 3,946-foot Mississippi River Bridge
- 1,150-foot Cable-Stayed Navigation Span
- $100 million
- HNTB Services
  - Preliminary & Final Design
  - Construction Consultation & Assistance
- Completion December 2003
- Design for Magnitude 8.5 Earthquake

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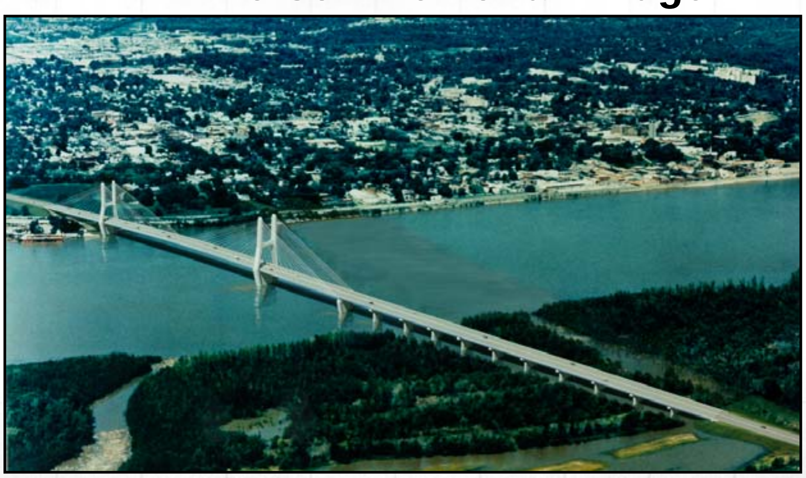
Bill Emerson Memorial Bridge



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Recurrence Interval for New Madrid Events

Magnitude	Recurrence Interval	Comments
1.0 - 1.9	2 Days	Not Felt
2.0 - 2.9	2 Weeks	Some Felt
3.0 - 3.9	4 Months	Almost Always Felt
4.0 - 4.9	4 Years	Minor Damage (1989)
5.0 - 5.9	40 Years	Damaging (1976)
6.0 - 6.9	80 Years	Destructive (1895)
7.0 - 7.9	200 Years	Devastating (1812)
8.0 - 8.9	500 Years	Disastrous (1812)

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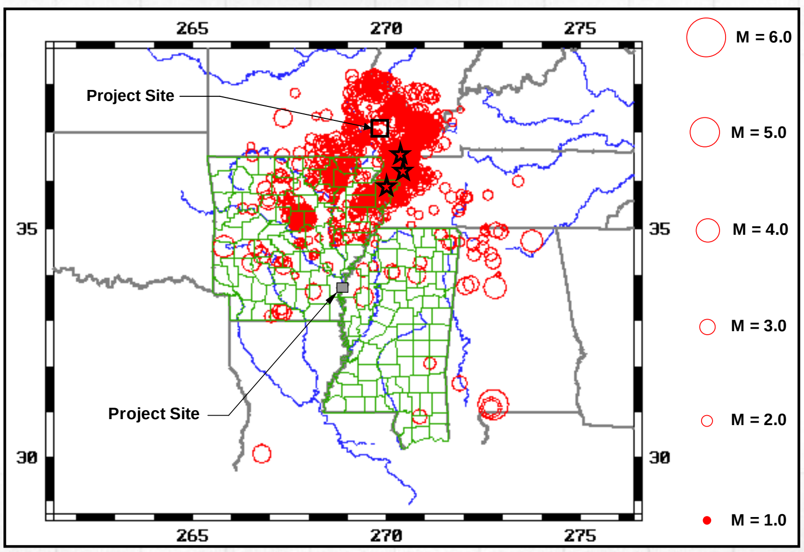

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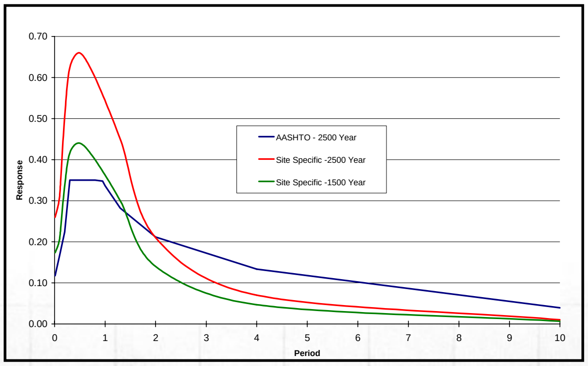
So what do we do with this data?

- Determine earthquake hazard



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So what do we do with this data?

- Determine design criteria
  - Cape Girardeau:
    - Design earthquake has 90% probability of not being exceeded in 250 years
    - Cable-stayed spans remain within the elastic range during the design event
    - Structure remains servicable after the design event

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So what do we do with this data?

- Determine design criteria
  - Great River Bridge:
    - 1500-year return period deterministic event
    - Cable-stayed spans remain within the elastic range during the design event
    - Structure remains serviceable after the design event

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So what do we do with this data?

- Site-specific geotechnical evaluation
  - Soil types
  - Shear wave velocity tests
  - Compression wave velocity tests
  - Hazard evaluation
- Develop site-specific spectrum
- Generate acceleration time history files

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Generate acceleration time history files

- Caleta de Campos recordings from 1985 Michoacan (Mexico City), Mexico earthquake
- Valpariso recordings from 1985 earthquake in Chile
- Pichulema recordings from 1985 earthquake in Chile

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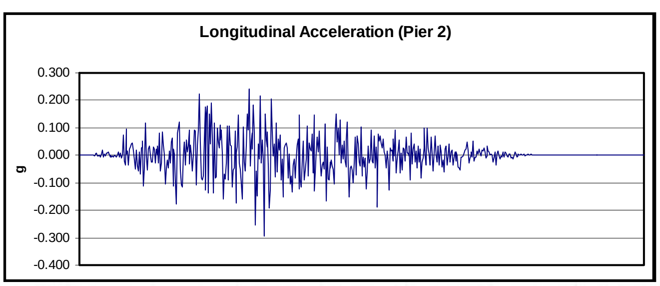
Generate acceleration time history files



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Generate Structural Model

- Full 3-D model in T187
- Every member explicitly modeled
- Linear elastic member properties
- Geometric and boundary conditions non-linearity

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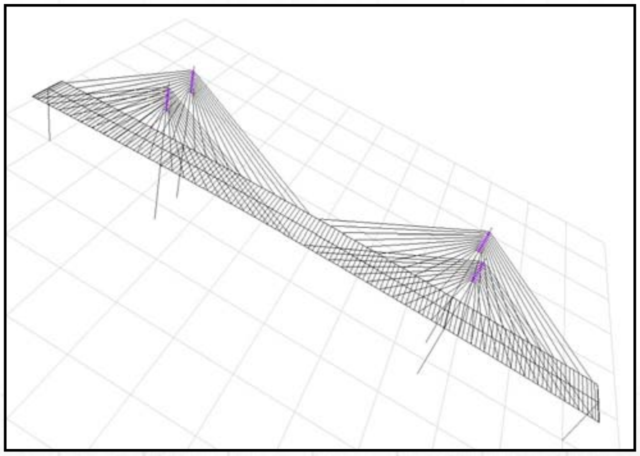
Generate Structural Model



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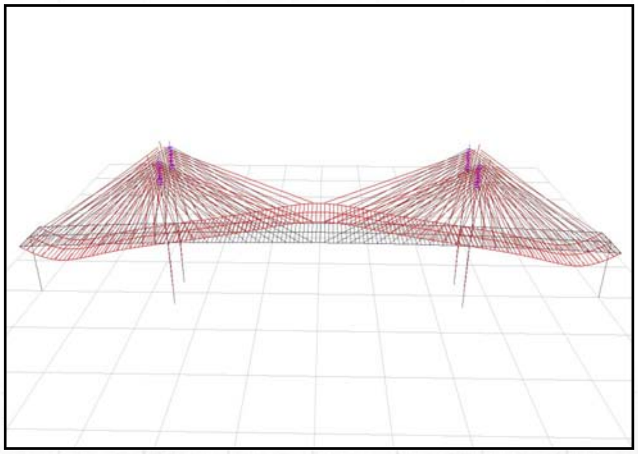
Generate Structural Model



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Evaluate the performance of the Bridge

- Longitudinal translation and rotation free at anchor piers - All main pier options
- Translation free at both tower piers
- Translation fixed at one tower pier
- Translation fixed at both tower piers
- Isolation bearings at all piers
- Earthquake shock transmission devices at both tower piers

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Consider Liquefaction Potential

- Soil Conditions
  - Missouri - Shallow Firm Clay on Limestone
  - Illinois - Deep Granular Alluvium on Limestone
- N = 25 Yields F.S. Against Liquefaction = 1.0
  - Missouri - No Liquefaction Hazard
  - Illinois - N = 10 to 30 to Depth of 70 feet (F.S. = 0.5)
- N > 15 Suggests No Lateral Spreading
  - Missouri - No Lateral Spreading
  - Illinois - N < 15 to Depth of 30 feet

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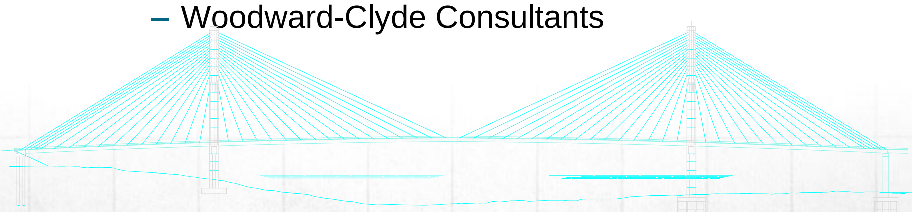
Acknowledgements

- OWNERS
  - Missouri Department of Transportation
  - Illinois Department of Transportation
  - Federal Highway Administration
- SEISMIC DATA
  - Woodward-Clyde Consultants



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Questions

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