SEISMIC DESIGN AND RETROFITTING FOR MISSOURI HIGHWAY BRIDGES

Presenting by

Anousone Arounpradith, MSCE, P.E.
Structural Project Manager, Bridge Division
Missouri Dept. of Transportation

Geotechnical and Bridge Seismic Design Workshop
New Madrid Seismic Zone Experience
October 28-29, 2004, Cape Girardeau, Missouri

Outlined Topics

- Bridge Overview
- Seismic Design for new bridges
- Seismic Retrofitting for existing bridges
- Summary

Bridge Overview

- First seismic design in 1989
- Structures in Missouri
  - Over 10,000 bridges in the state inventory
  - Currently 2,300 (23%) bridges in Seismic Cat. B, C & D
- Typical Bridges in Missouri
  - Plate Girder, PS I-Beams, Solid Slab, etc.
  - Multiple column bents, pile bents (steel and concrete)
  - Spread and Pile Footings

PS I-Beams Superstructure

Plate Girder Superstructure

Multiple Concrete Column Bents

Multiple (Steel) Pile Cap Bents

Integral (monolithic) Abutment

Non-integral (free-standing) Abutment

Design & Retrofitting - 9

Steel Pile Footings w/anchors

Design & Retrofitting -10

Spread Footings on Rock

Outlined Topics

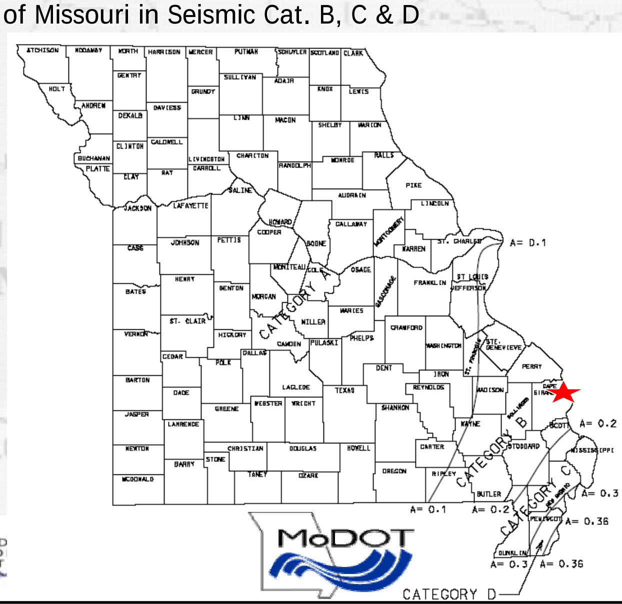
- Bridge Overview
- Seismic Design for new bridges

Seismic Design

- Design References
  - 16th AASHTO Div. I-A (1996) and interims
  - Lam and Martin (1986)
  - Priestley and Seible (1996)
  - Wilson, J.C. (1988)
  - Etc.

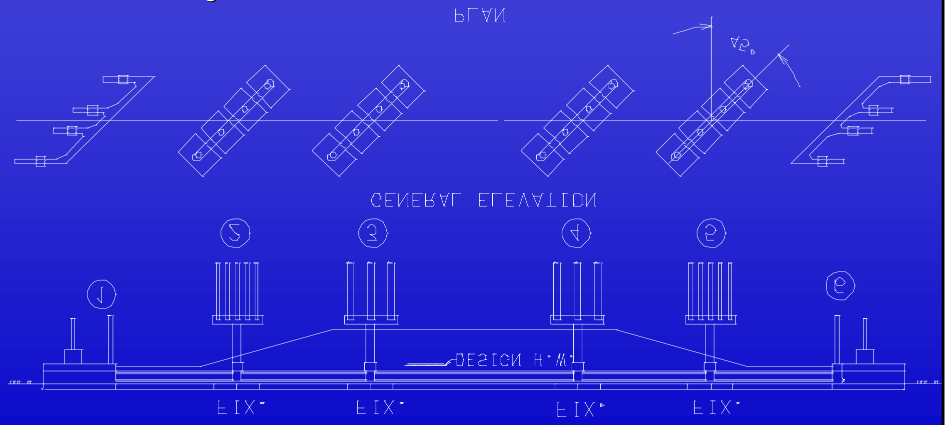
Design & Retrofitting -13

- Seismic Map for Missouri
  - Rock Acc. Coeff. = 0.10 to 0.36
  - <1/3 of Missouri in Seismic Cat. B, C & D



Bridge Layout

- Multiple spans bridge with large skew
- Monolithic abutments with interior wing walls
- Multiple column bents
- Pile footings

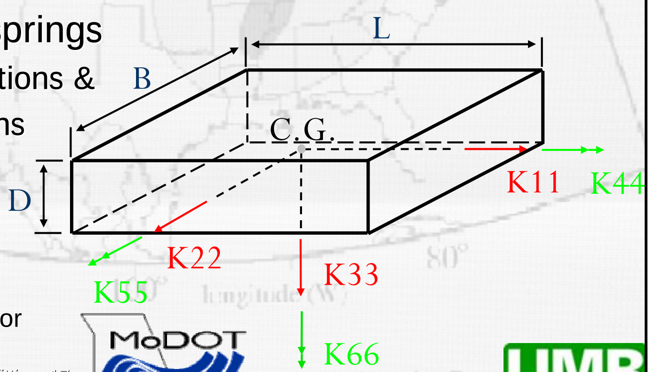


Seismic Design

- Analysis/Design
  - Multi-mode response spectrum method
  - Liquefaction
  - Soil-Foundation Interaction
    - Footing springs
    - Abutment springs
    - Pile springs

Seismic Design

- Spread Footing Springs (Lam & Martin)
  - Equivalent circular footing
  - Six linear springs
    - 3 Translations &
    - 3 Rotations



$[K] = (\beta)(\alpha)[Ko]$

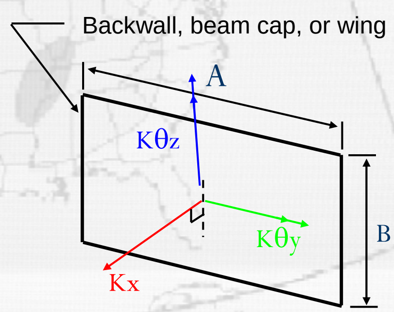
Ko – diagonal stiffness

β – embedment factor

α – shape correction factor

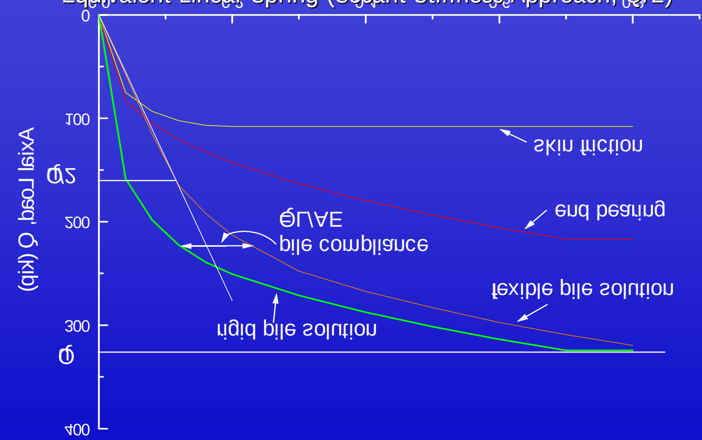
Seismic Design

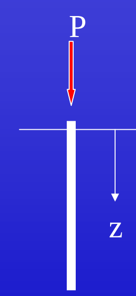
- Abutment Springs
  - Wilson's models (1988)
  - 3 linear springs
    - Translation and
    - Two Rotations



Pile Axial Spring

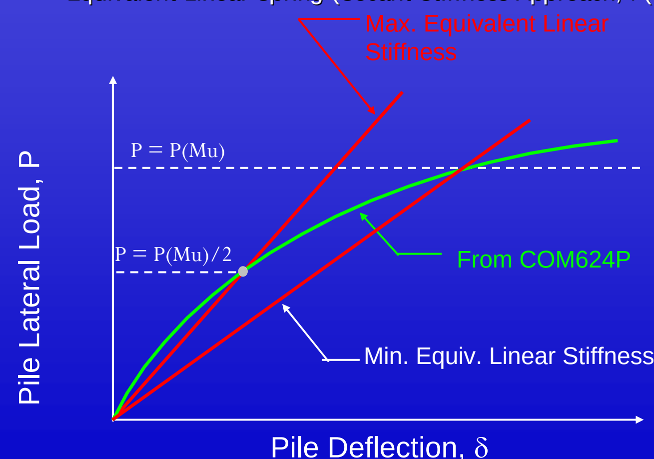
- SPILE Program (Urzua, 1993)
  - Piles subject to axial loads
  - Non-linear curve for soil-pile interaction
  - Equivalent Linear Spring (Secant Stiffness Approach, Q/2)

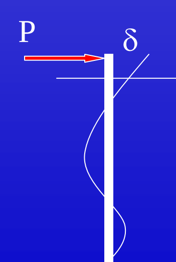




Pile Lateral & Rotational Springs

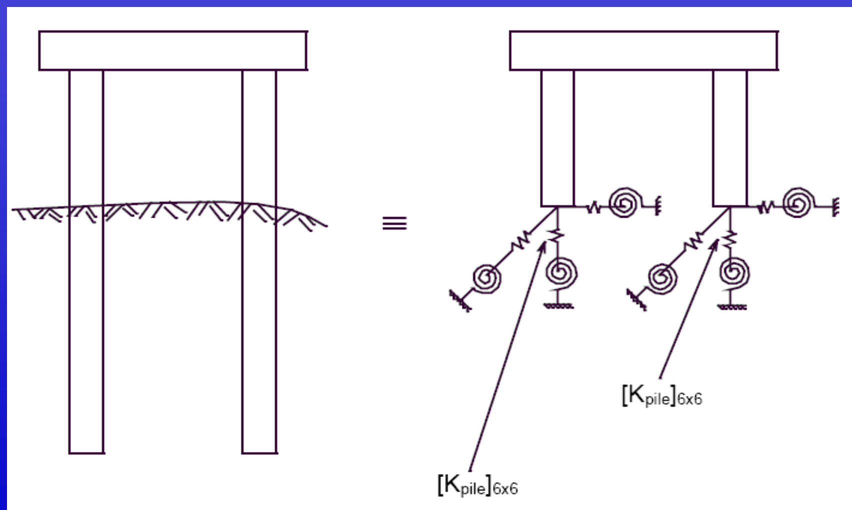
- COM624P Program (Wang & Reese, 1993)
  - Piles subject to lateral loads
  - Non-linear curve for soil-pile interaction
  - Equivalent Linear Spring (Secant Stiffness Approach, P(Mu)/2)





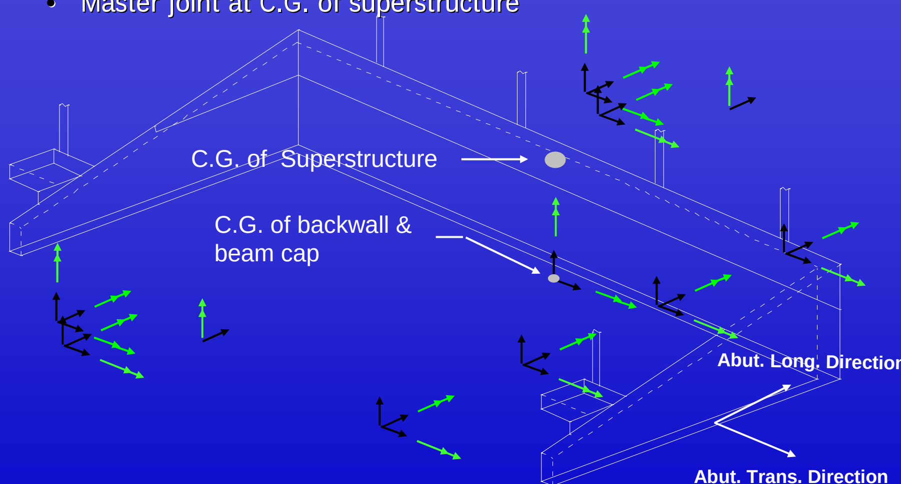
Foundation Spring Model

- Drilled shafts
- Footing on piles or rock



Abutment Springs

- Many equiv. linear springs
- Master joint at C.G. of superstructure

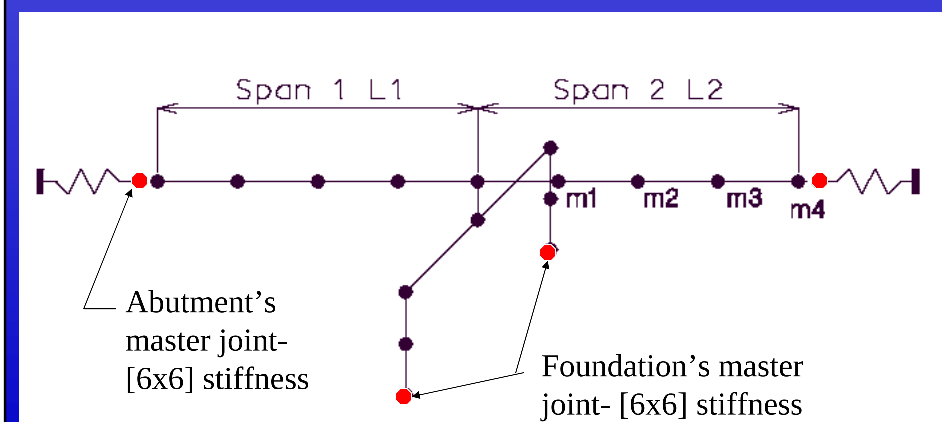


Seismic Design

- Analysis/Design (cont'.)
  - Rigid Body Transformation Technique
    - Combine springs (stiffness) at a master joint
    - Reduce # of degree-of-freedoms
    - Take account of coupling effects
    - Demand seismic forces for abut.'s components

Structure Modeling

- Multi-mode Response Spectrum Analysis
- [6x6] stiffness at abutment's master joint
- [6x6] stiffness at foundation's master joint
- "Full-Zero" abutment springs – 2 separated seismic analyses



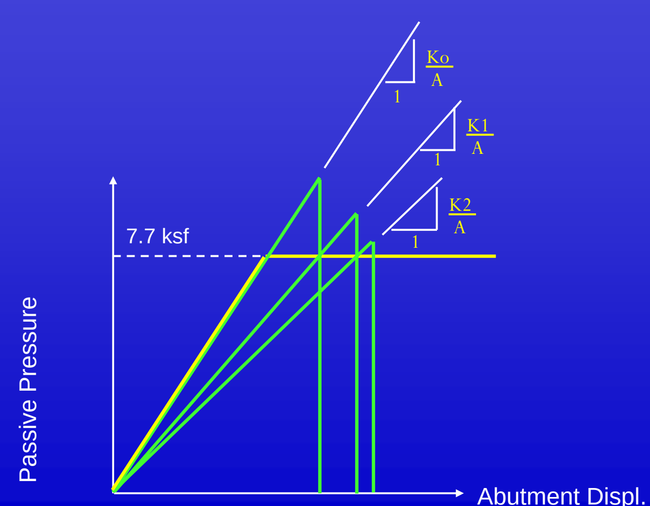
Seismic Design

- Analysis/Design (cont'.)
  - Iterative Abutment Procedure
    - Check soil passive pressure <7.7 ksf

Design & Retrofitting -25

Passive Soil Pressure vs. Abutment Displ.

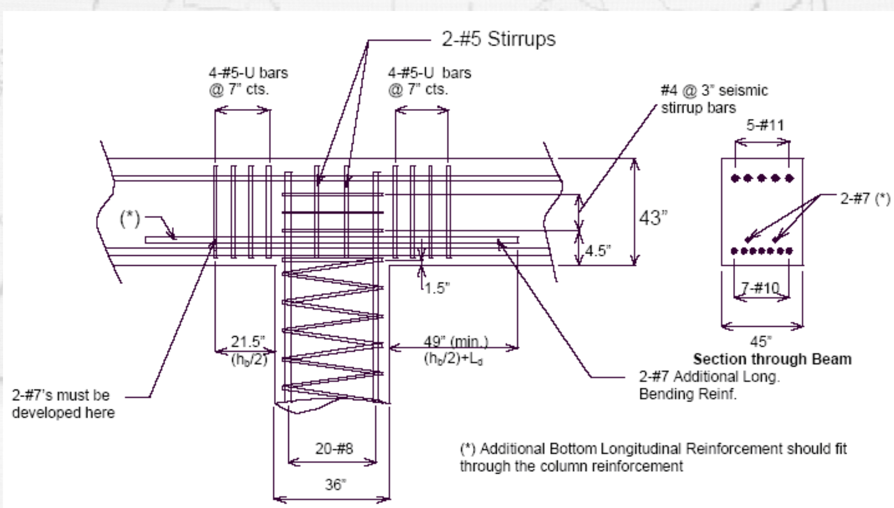
- Max. passive soil pressure 7.7 ksf at abutments
- Reduce abutment springs when abutment's pressure > 7.7 ksf



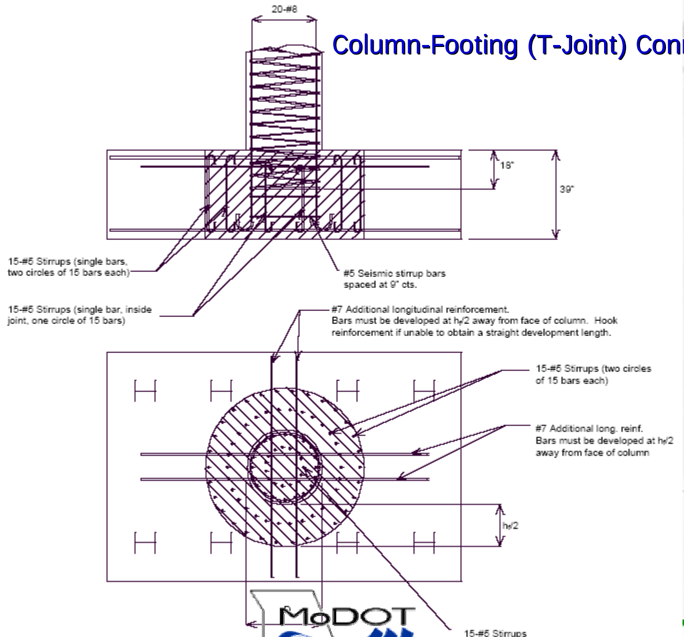
Seismic Design

- Analysis/Design (cont'.)
  - Iterative Abutment Procedure
    - Check soil passive pressure <7.7 ksf
    - Check pile stresses < allowable stresses
    - Check abutment's displacement at the master joint
  - Min. support length at expansion gaps
  - Consider both elastic and plastic designs
  - Design all main connections
    - Column to footing or beam cap (T-Joint Design)
    - Anchor bolts, shear blocks, crossframes
    - Etc.

Column-Beam Cap (T-Joint) Connection



Column-Footing (T-Joint) Connection



Outlined Topics

- Bridge Overview
- Seismic Design for new bridges
- Seismic Retrofit for existing bridges

SEISMIC RETROFIT

- Major bridge rehabilitations
  - Deck replacement
  - Bridge widening
  - Case-by-case basis
- Retrofitting vs. New bridge
  - Evaluate Pros and Cons
  - Cost-effective comparison
  - Availability of funding

SEISMIC RETROFIT

- Retrofit design
  - FHWA-RD-94-052 (May 1995)
  - Multi-mode Response Spectrum analysis
  - Capacity/Demand Ratio
- Types of Retrofitting
  - Restrainers
  - Bearing replacements
  - Deepen beam caps
  - Steel column jacketing
  - Widen footings

SEISMIC RETROFIT

- Restrainer System

SEISMIC RETROFIT

- Steel Column Jacketing

SEISMIC RETROFIT

- Retrofitting footings

NATURAL HAZARDS MITIGATION INSTITUTE

Design & Retrofitting -35

MoDOT

UMR UNIVERSITY OF MISSOURI-ROLLA

Outlined Topics

- Bridge Overview
- Seismic Design for new bridges
- Seismic Retrofit for existing bridges
- Summary

NATURAL HAZARDS MITIGATION INSTITUTE

Design & Retrofitting -36

MoDOT

UMR UNIVERSITY OF MISSOURI-ROLLA

SUMMARY

- Multi-mode Response Spectral Analysis
- Soil-Foundation Interaction
- Rigid Body Transformation
- T-Joint Connection Design
- Rigorous Analysis and Design
- Time-consuming Design

Questions ?

More Information,

Website: www.modot.state.mo.us

Look for "Business/bridge design/section 6.1 & 6.2"

Email: Anousone.Arounpradith@modot.mo.us.gov

Thank you!