2009 Caltrans-PEER Seismic Seminar Series

# Seismic Response and Capacity Evaluation of Exterior Sacrificial Shear Keys of Bridge Abutments

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#### History of UCSD Work on Abutments

- Post-tensioned Abutments (2002)
  - Megally, Silva, and Seible
- Sacrificial Shear Keys (2007)
  - Bozorgzadeh, Bauer, Restrepo, and Ashford
- Abutment Backfill Models (2007)
  - Bozorgzadeh, Ashford, and Restrepo
  - Initially considered diaphragm-type abutments
  - Worked with EMI on backfill soil types
  - Completed testing on seat-type abutment





# Acknowledgments

- The California Department of Transportation (Caltrans) is gratefully acknowledged for the financially support of the experimental research on sacrificial exterior shear keys.
- This research was carried out at UC San Diego. The participation of the UCSD faculty, staff, and students is also acknowledged.





#### Schematic of Exterior Shear Key in Bridge Abutments







#### 1994 Northridge Earthquake Over half of damaged bridges suffered abutment damage





# **Experimental Work**

- Five test series, each including two test units were built at a 40% scale.
- Main variables:
  - Construction joint.
  - Amount and configuration of vertical reinforcement.
  - Amount and configuration of horizontal reinforcement.





#### Elevation View of Reinforcement Layout of the Proposed Model





#### Shear Key Test Specimens Under Construction





#### **Test Setup**





### Failure of Exterior Shear Keys of Two Test Series



**Oregon State** 

- Failure occurred in a diagonal strut in the stem wall.
- No sliding at the interface of shear key-abutment stem wall occurred.

- Performed as structural fuses with sliding shear failure.
- Diagonal cracks formed in the stem wall but the maximum width of cracks were 0.012".

### Load-Displacement Curves



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# Conclusions

- A model for evaluation of capacity of shear keys under lateral force was developed based on Strut-and-Tie models.
- The proposed model showed better agreement with test results than the current shear friction model.
- The current shear friction model underestimates shear key capacity which may lead to damage of abutment wall or supporting piles.



# Conclusions

- Based on results of experimental work, several recommendations were proposed for construction details:
  - Using smooth construction joint.
  - Shear key vertical reinforcement bars should be the only reinforcement connecting the shear key to the abutment stem wall.
  - Headed bars or hanger bars can be used in the stem wall to carry the force transmitted by the shear key.





Research results implemented along I-905 in San Diego in September 2007

Most testing carried out in 2003/4, final report dated October 2007

Caltrans implements good results quickly, in this case before final report issued.

#### **Shear Key Construction**







### **Completed Keys**





### **Results Available at UCSD**

- SSRP-2001/22, May 2002: "Seismic Response of Sacrificial Shear Keys in Bridge Abutments," S.H. Megally, P.F. Silva, F. Seible, 215p.
- SSRP-04/14, October 2007: "Seismic Response and Capacity Evaluation of Exterior Sacrificial Shear Keys in Bridge Abutments," A. Bozorgzadeh, H.L. Bauer, J.I. Restrepo, S.A. Ashford, 40p.
- SSRP-07/12, May 2007: "Experimental and Analytical Investigation on the Stiffness and Ultimate Capacity of Bridge Abutments," A. Bozorgzadeh, S. Ashford, and J. Restrepo, 196p.

