Analysis of Pier Structures Supported on Battered Piles Using MOTEMS

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Prevention First 2008 Conference
September 10, 2008

Purpose of Presentation

- Review MOTEMS batter pile evaluation procedure
- Review effects of deck stiffness on performance
- Present case study
- Show not all batter pile systems perform poorly

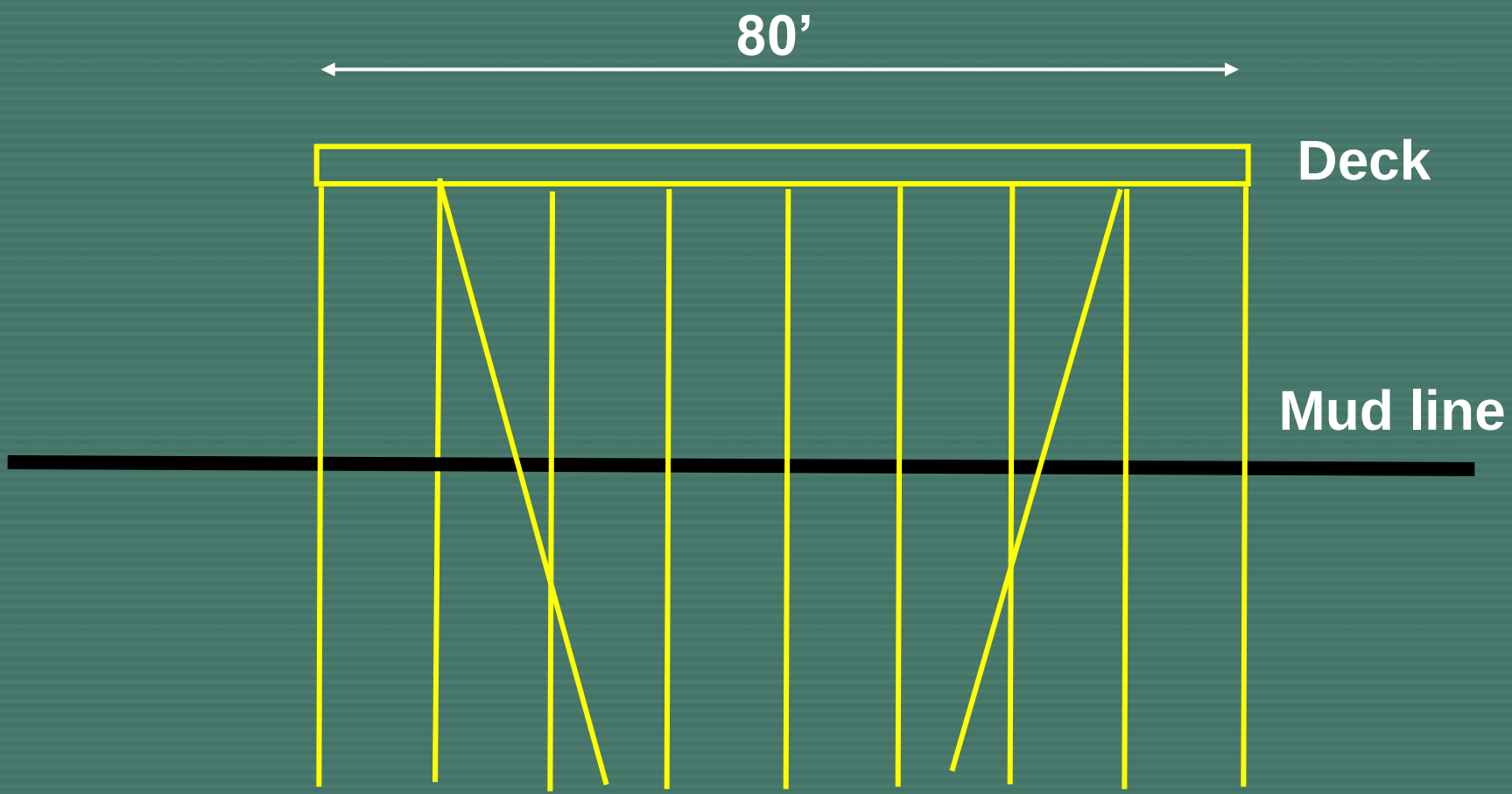
MOTEMS Evaluation Procedure

- Identify the failure mechanism of the batter pile-deck connection
- Release the lateral load between the batter pile and the deck when the lateral failure displacement is reached.
- Push on the structure until subsequent failure(s) have been identified.

Batter Pile Rules

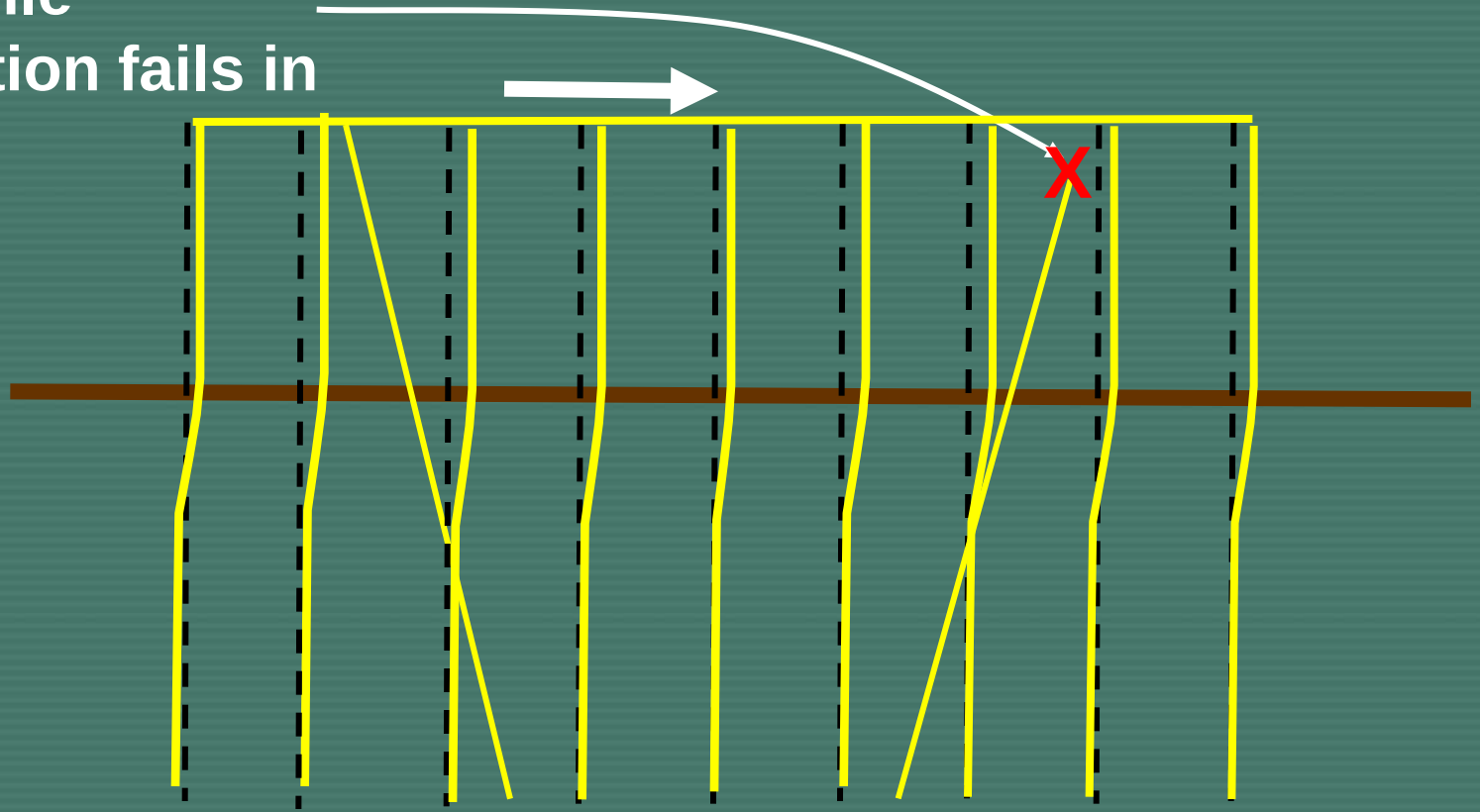
- Rule No. 1 - Tension piles almost always fail first at the connection
  - Geotechnical compression capacity is almost always greater than tension capacity.
  - Tension capacity of pile is almost always greater than connection
- Rule No. 2 – Rule No. 1 is not always true!!

MOTEMS Example



First Failure

Batter pile connection fails in tension

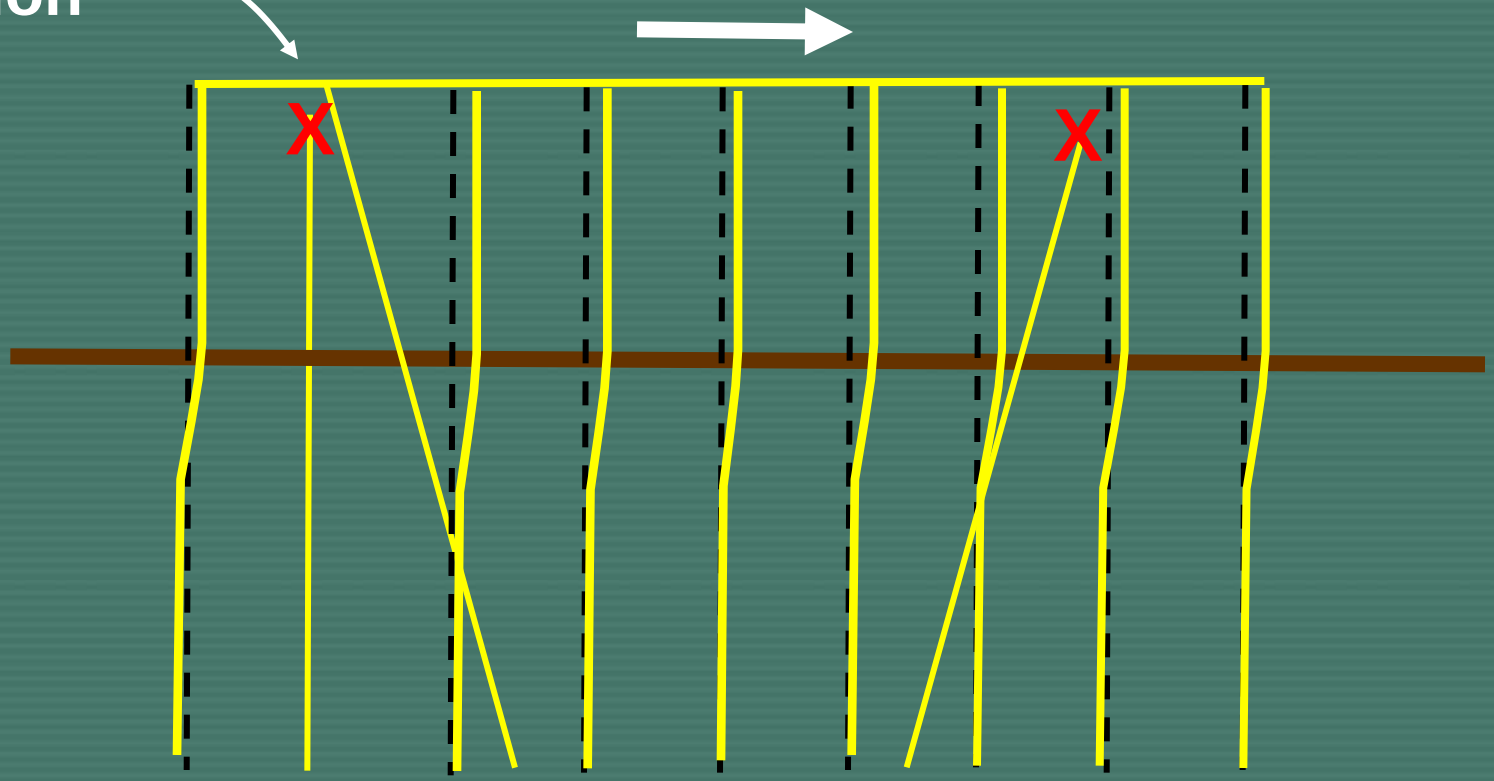


First Failure Issues

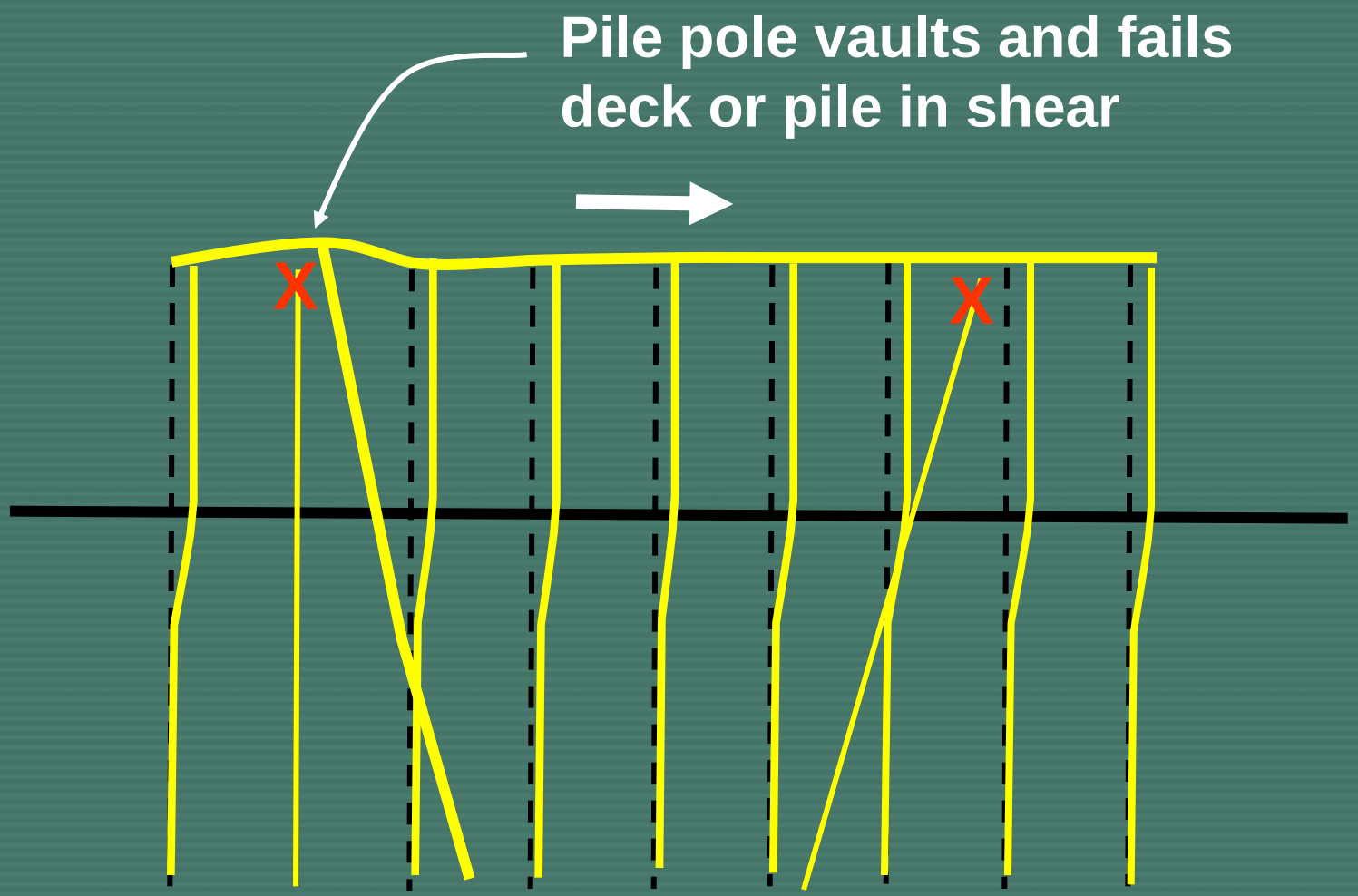
- **Is tension failure ductile or brittle?**
- **Will tension pile act in compression in later cycles or is it lost to the system?**
  - Model as compression only if appropriate
  - Need to fully understand connection failure mode
- **Connection detailing is important!!**

Second Failure

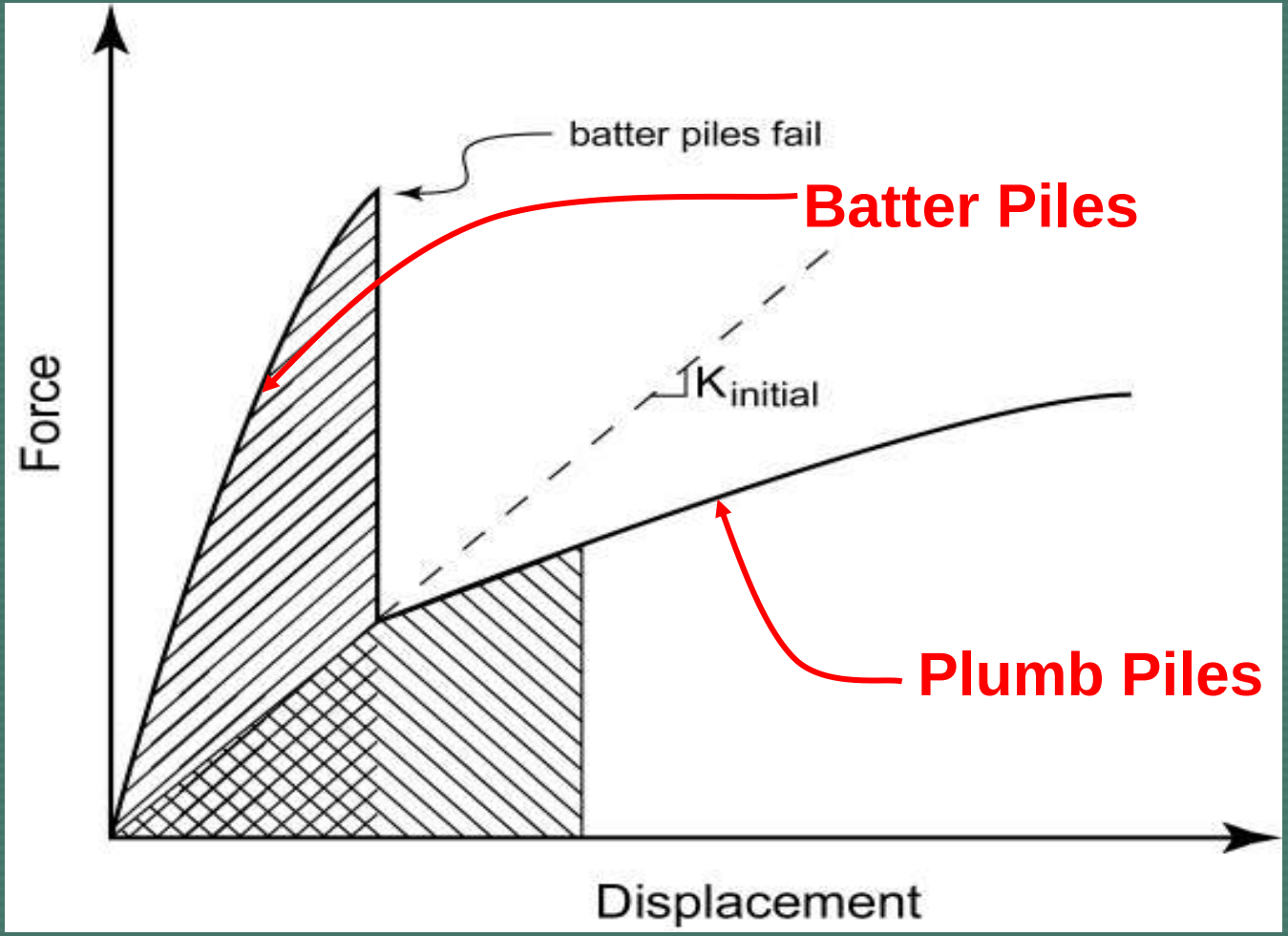
Plumb pile connection fails in tension



Third Failure

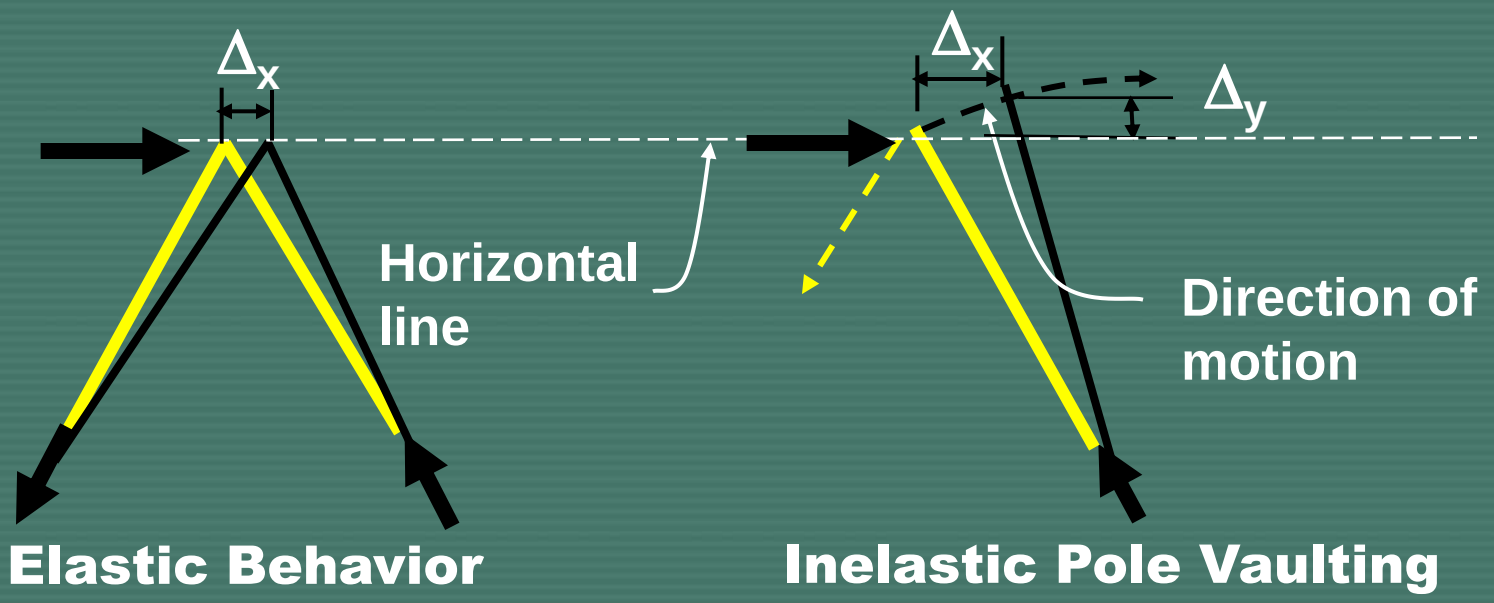


Pushover Plot (From MOTEMS)

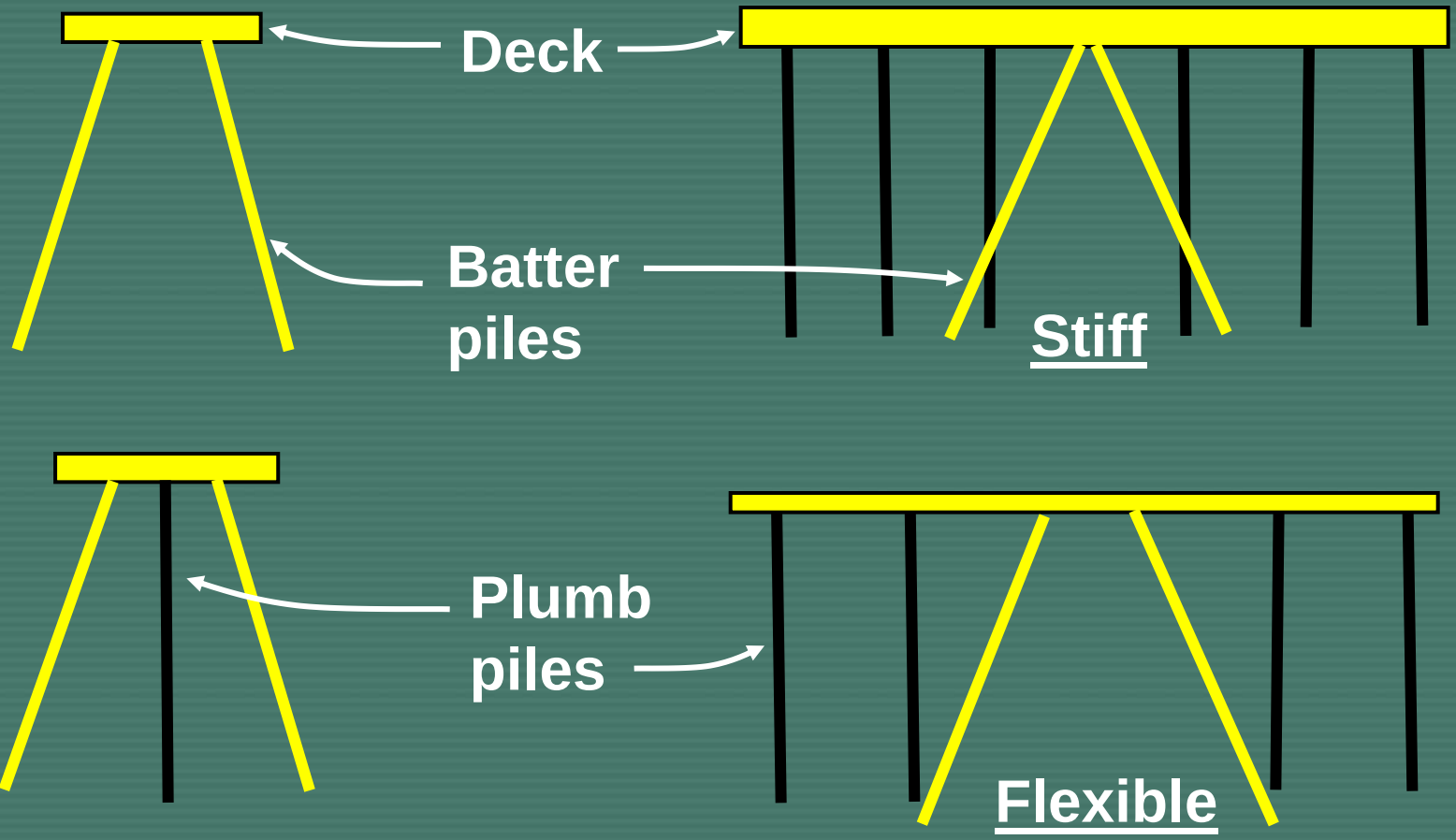


Pole Vaulting

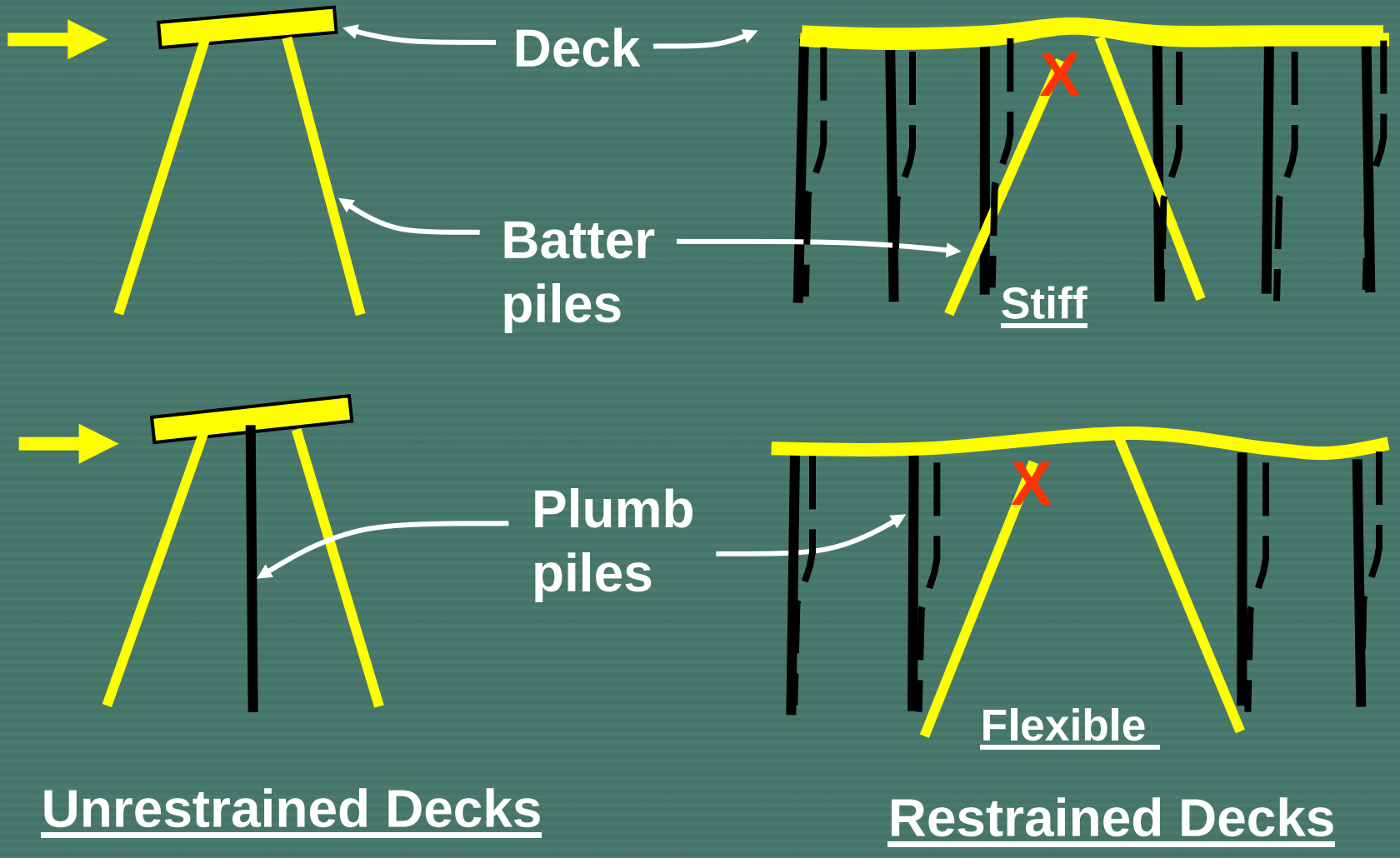
- Batter piles will “pole vault” i.e. displace vertically in the inelastic range when tension pile fails
- A deck structure that allows vertical displacement will minimize pile and deck forces from pole vaulting



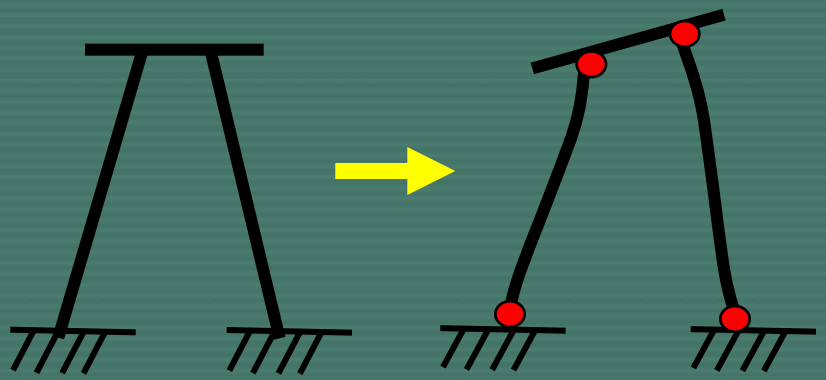
Types of Deck Restraint



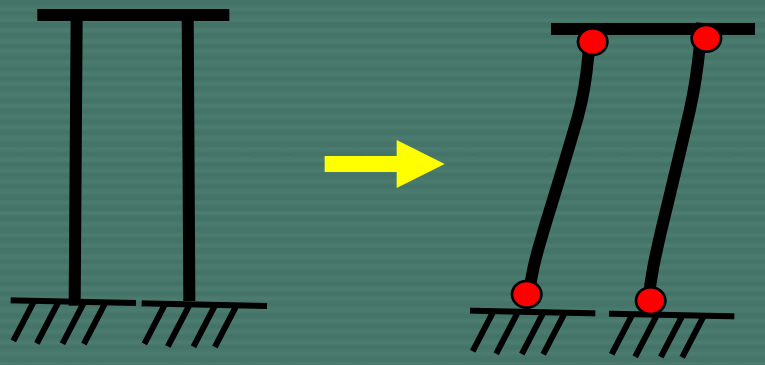
Inelastic Displaced Shapes with Pole Vaulting



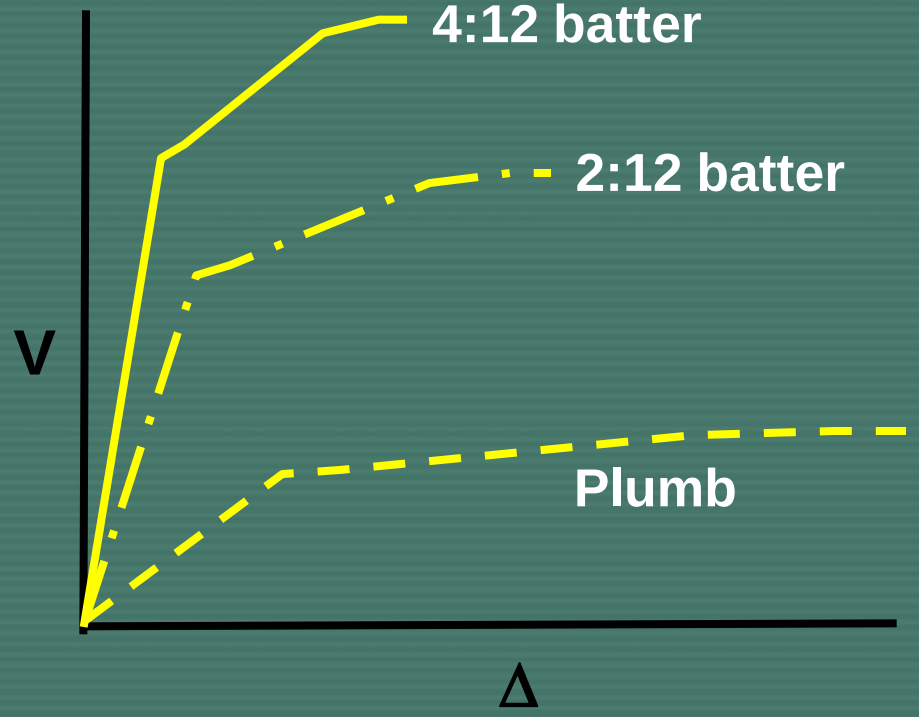
Battered vs. Plumb Pile Frame Pushover



Battered Frame

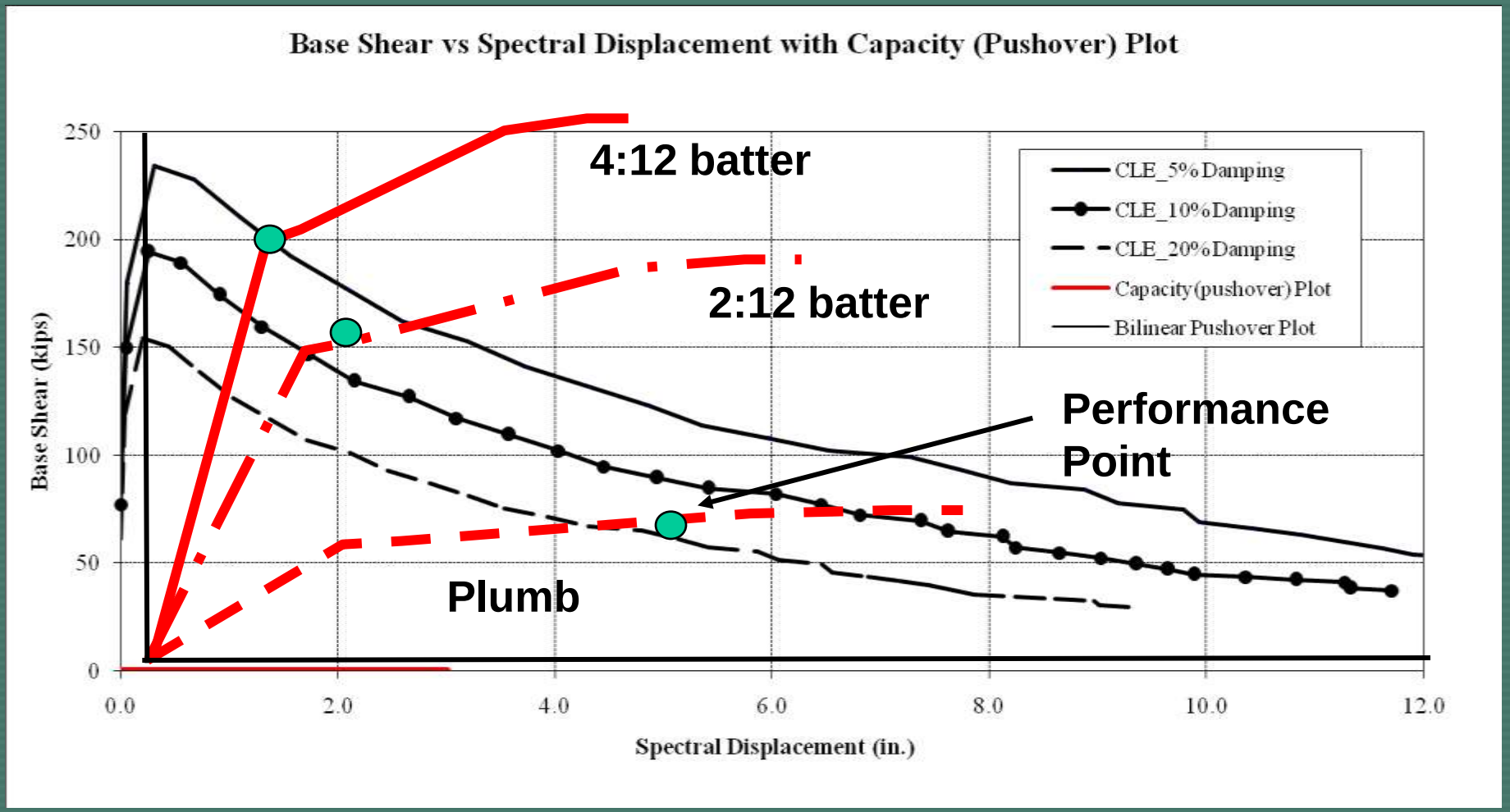


Plumb Pile Frame



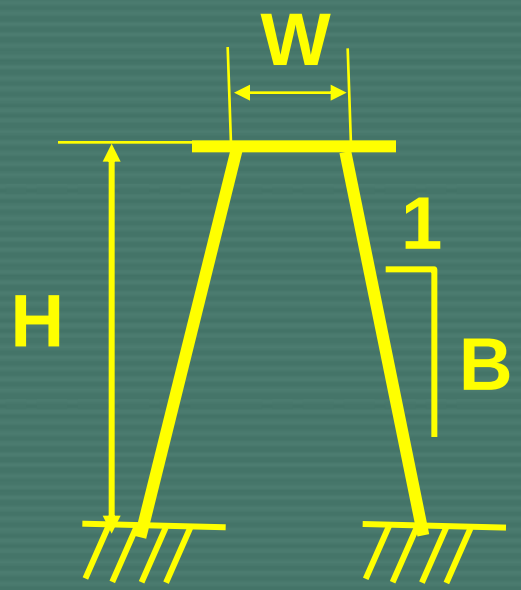
Pushover Plot

Battered vs. Plumb Pile Frame Displacement



Conclusion – Unrestrained Battered Frames

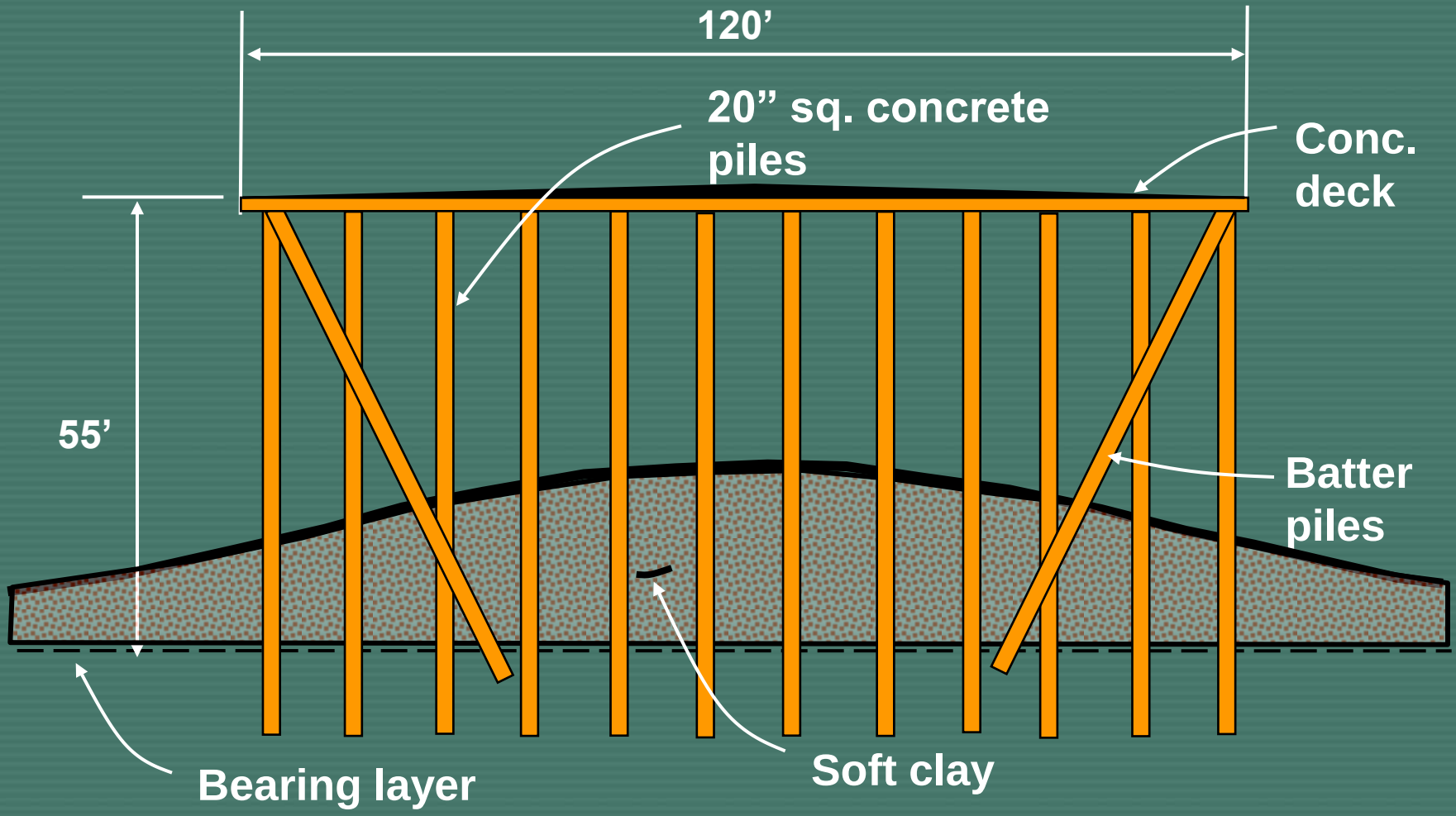
- **Batter piles in unrestrained frames are stiffer and stronger than plumb pile frames with the same members yet they can have significant ductility**
- **Key Factors**
  - Connection strength and ductility
  - Batter – B
  - Width between piles – W
  - Height – H



Example Pier Retrofit Concept Study

- Concrete Pier
- Not a M.O.T.
- Thin concrete deck
- Plumb piles at close spacing
- Transverse direction discussed

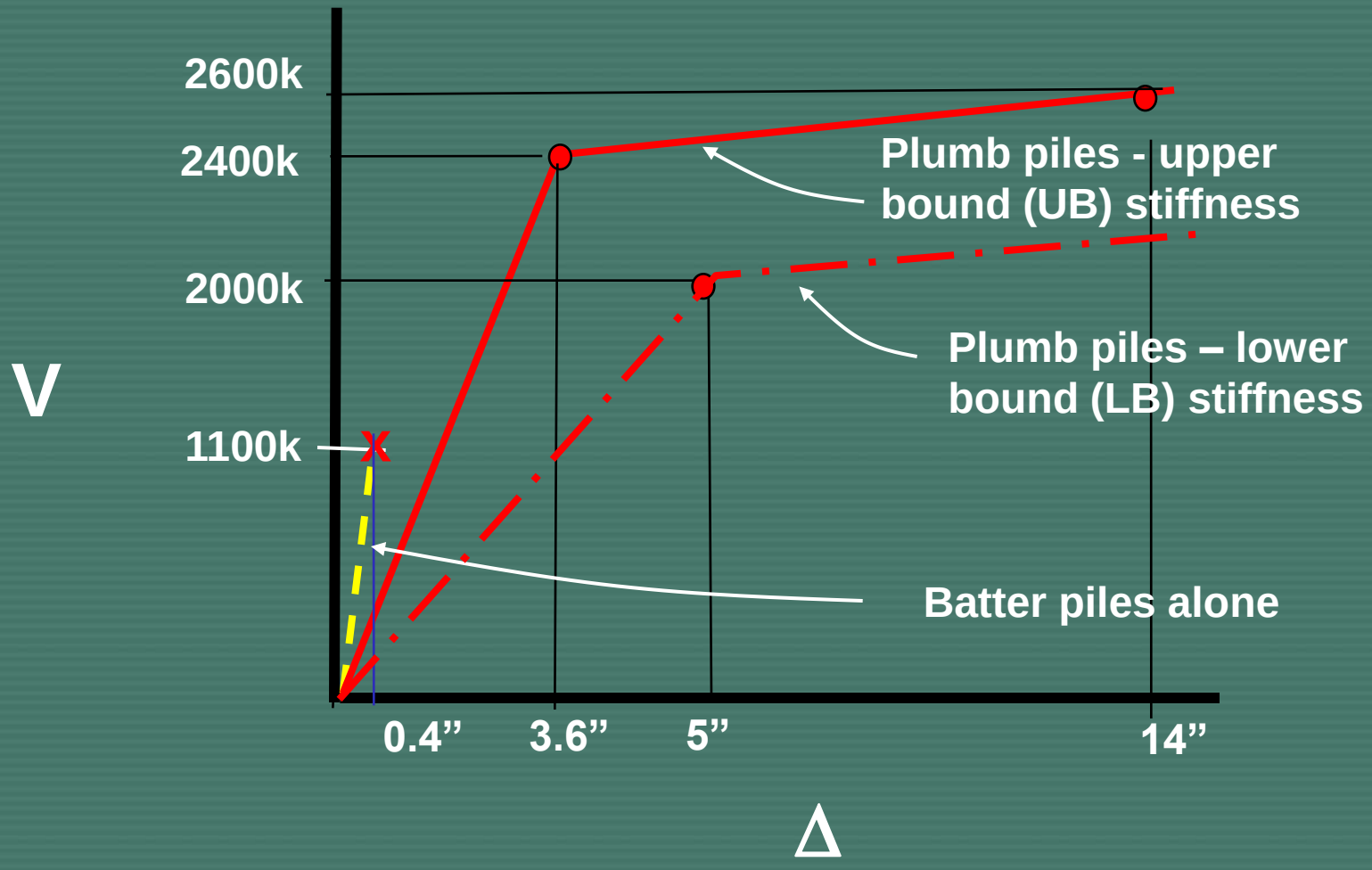
Example Pier Transverse Section



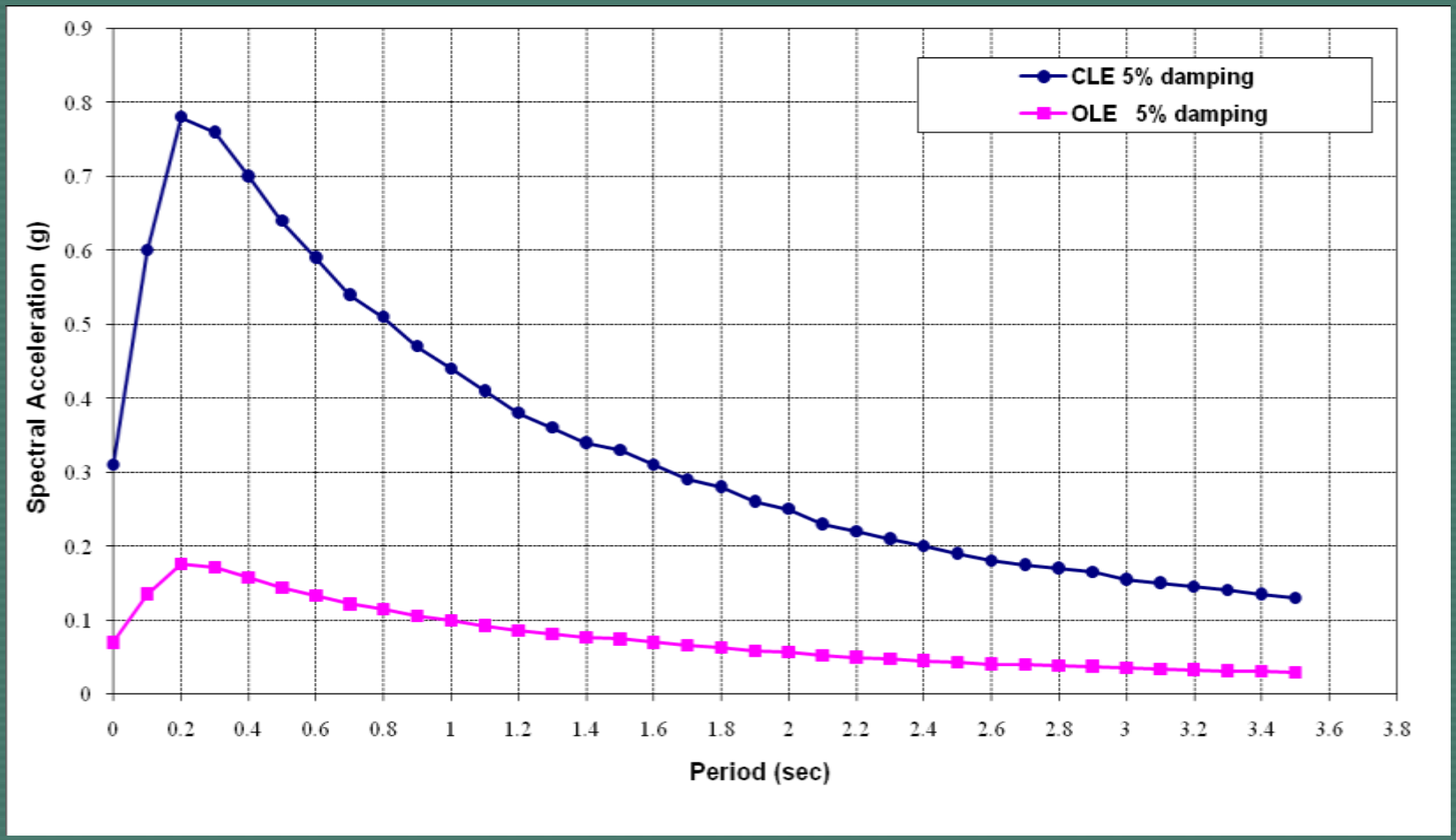
Tension Pile Capacity

- Outer tension piles had minimal dead load
- Soil pullout values were low
- Connections were found to be strong enough to develop soil tension capacity
- Piles likely to slip and walk out of soil

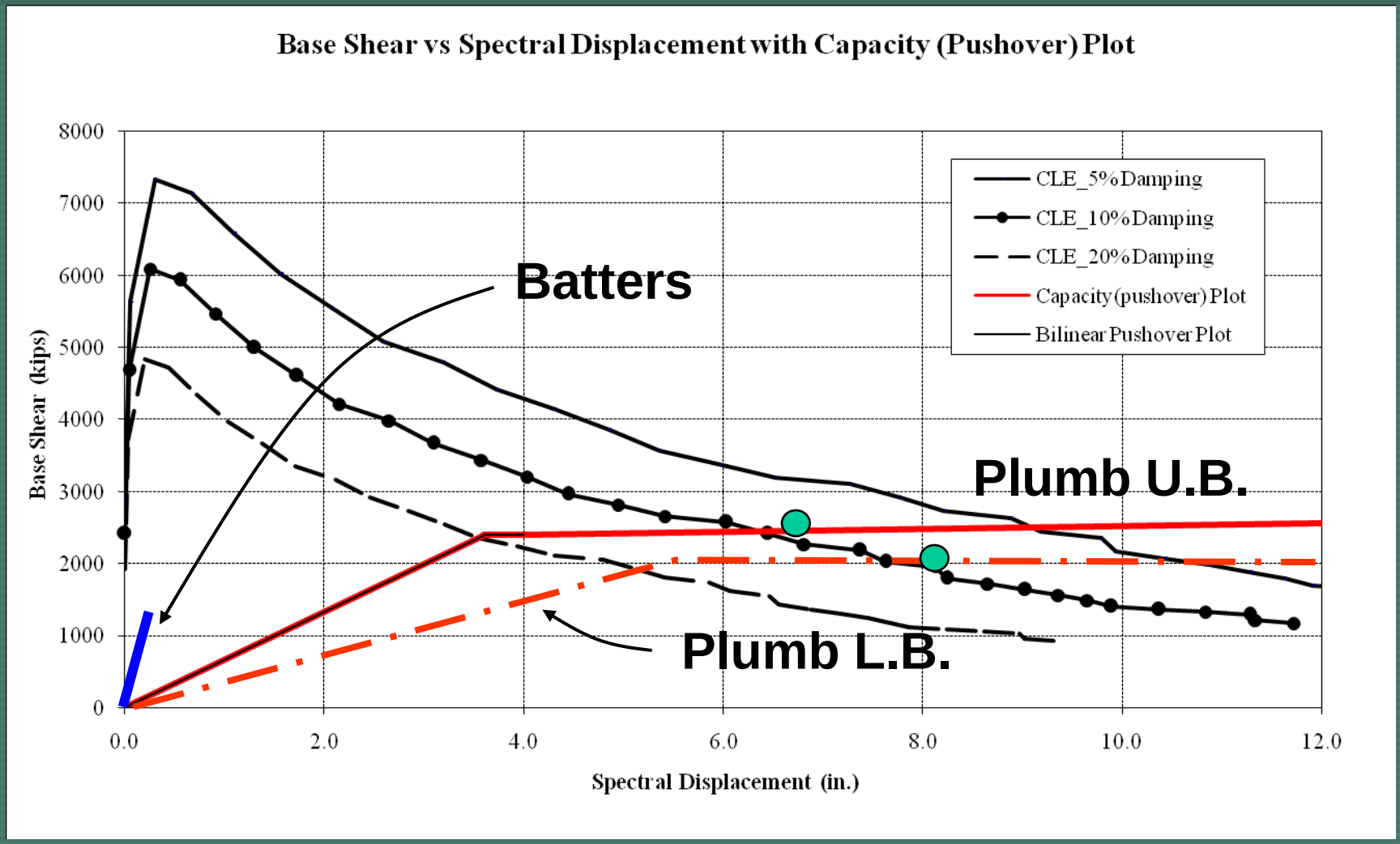
Pushover Plot for Pier



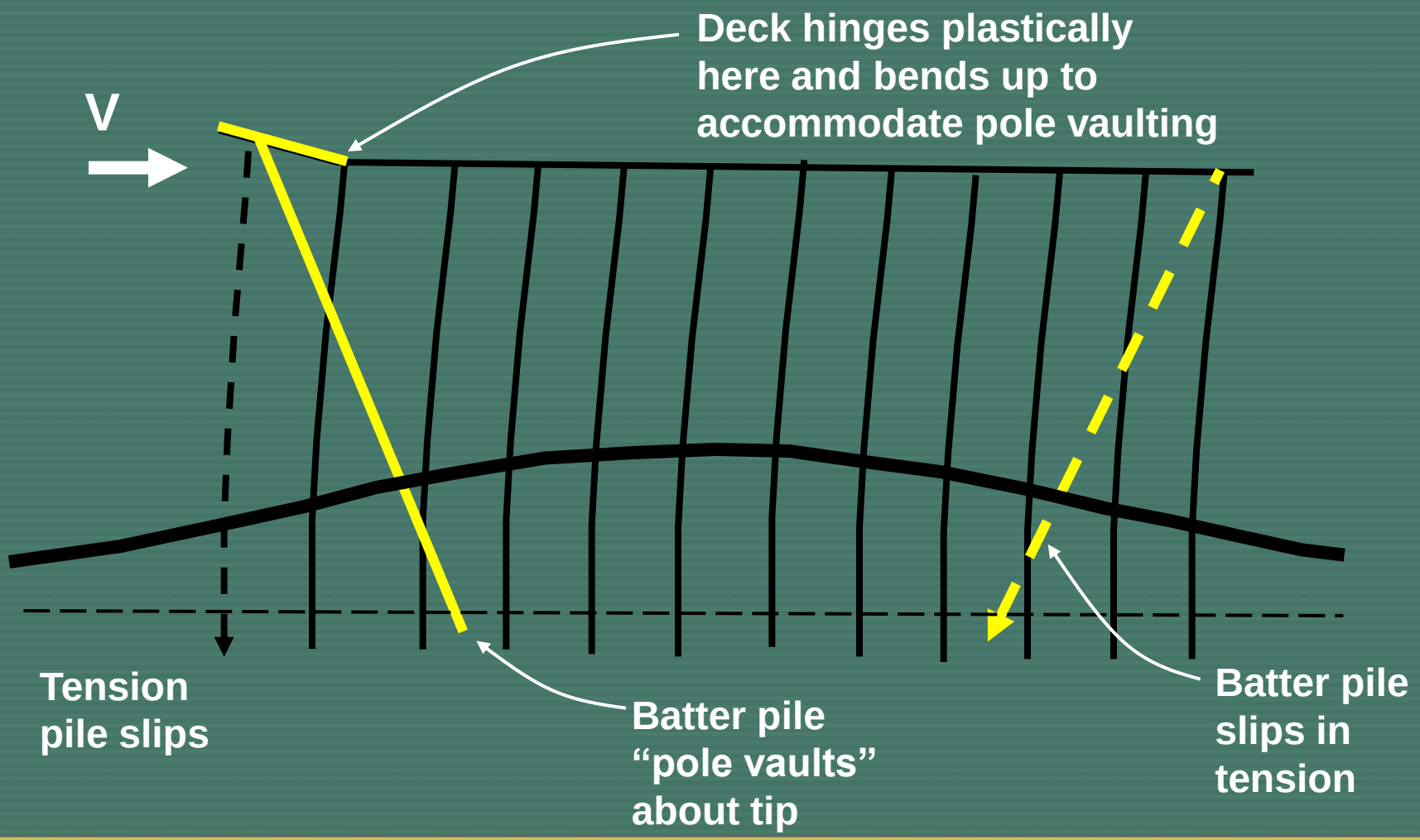
Site Specific Response Spectra



Estimate Displacement Demand Using ADRS



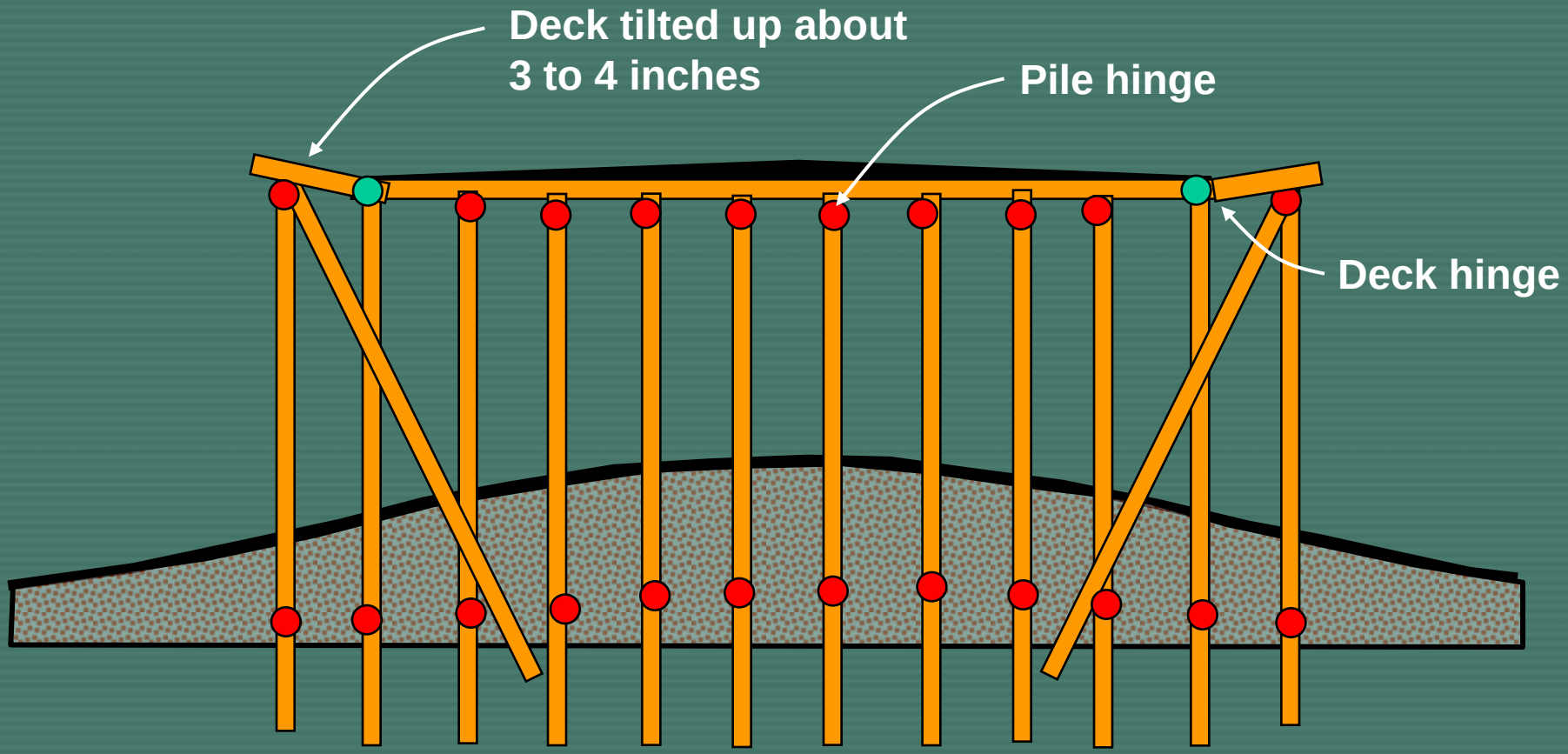
Transverse CLE Performance



Transverse CLE Performance

- For this structure tension piles appear to slip due to minimal embedment. (i.e. Rule 1 does not apply)
- Hinge forms in deck – damage acceptable
- Tension piles (batter and plumb) likely to walk out of soil on subsequent cycles

Post CLE Earthquake Condition



Summary

- **MOTEMS provides on general guidance with respect to batter pile analysis and design**
- **Batter piles induce inelastic vertical displacements into the deck due to pole vaulting after failure of tension pile**
- **Therefore seismic performance is very dependant on the deck configuration.**
  - Unrestrained decks do better
  - Restrained decks do worse
  - Tension connection ductility also important

Credits

- **BERGER / ABAM Engineers Inc.**