Flexible Approach Walls

Navigation Systems

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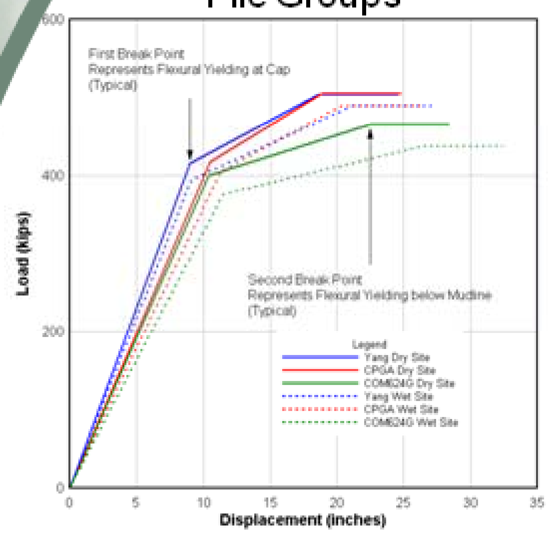
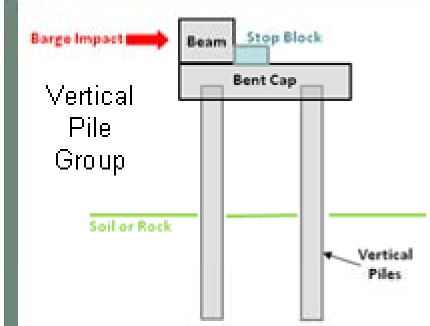
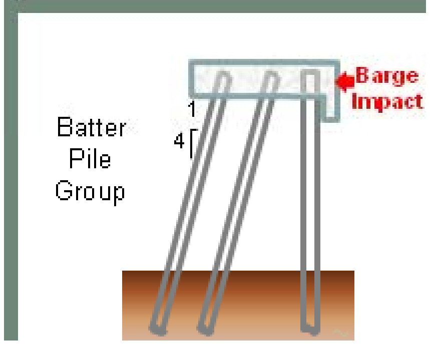
Technology Exchange Meeting

28 October 2014

Pushover Analysis of Pile Groups







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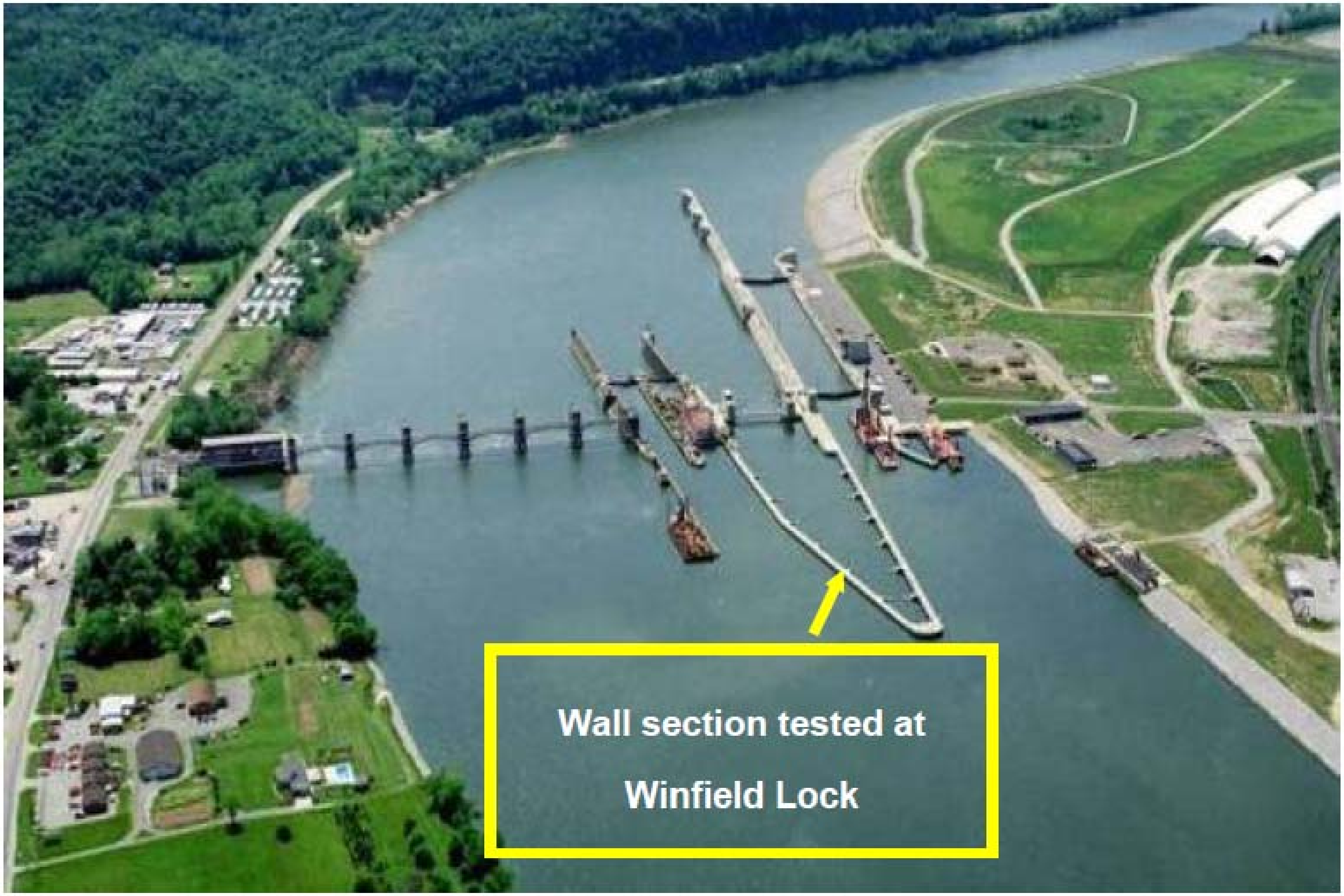
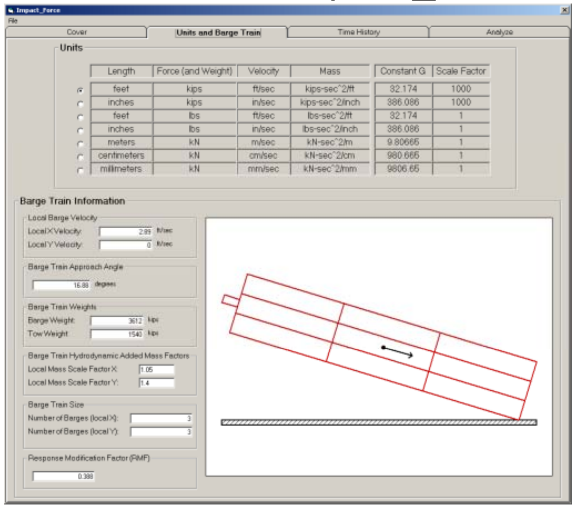
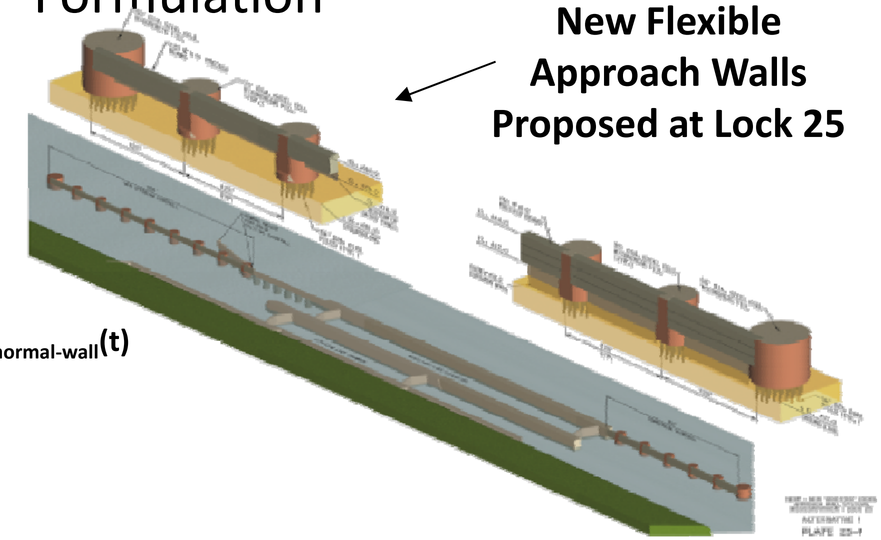


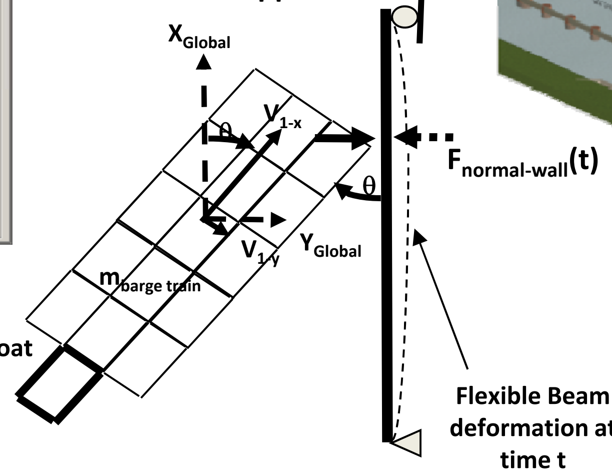
Full-scale Barge Train impact experiments were performed with a fully-ballasted 3x3 barge train with the flexible approach wall system at Winfield L&D

Impact_Force Software Scaling Time-History Formulation

PC-software Impact_Force



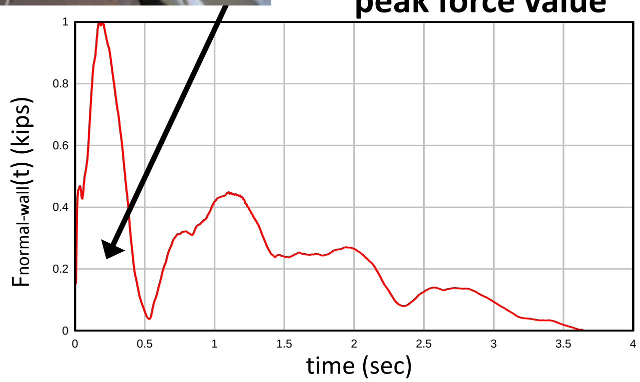




Winfield Barge Impact Test #10

Normal force measurement

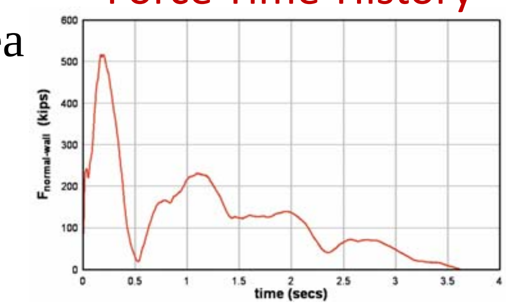
- Normalized to a unit peak force value



$$\int_{t_1}^{t_2} F(t)dt = F_{max} \bullet \text{Unit pulse area}$$

$$F_{max} = \frac{m_{bargetrain-normal} \bullet (v_{1-normal}) \bullet RMF}{\text{Unit pulse area}}$$

Resulting Scaled Force Time-History

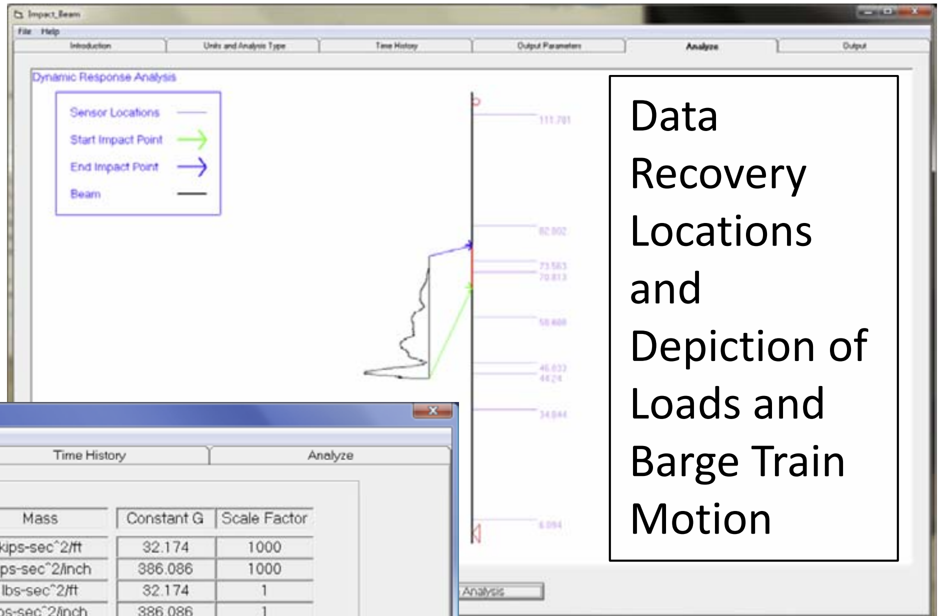


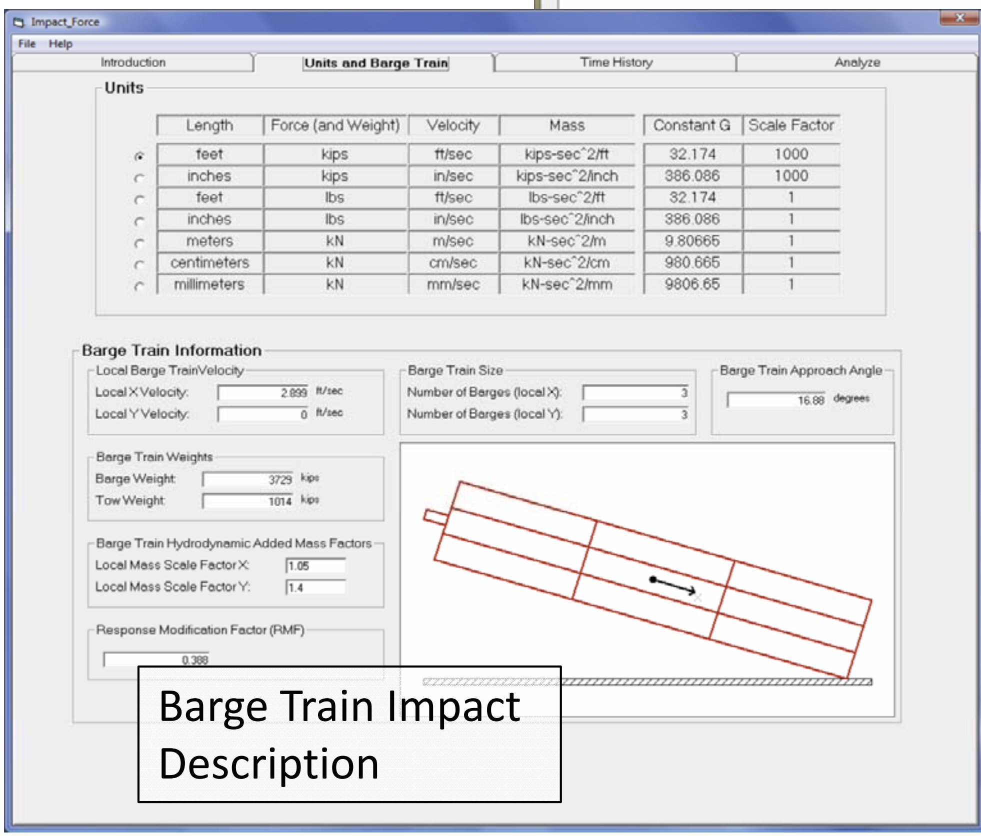
Force time history F(t), to be used in the dynamic impact beam analysis code Impact_Beam, is the unit time history force scaled by F_{max}

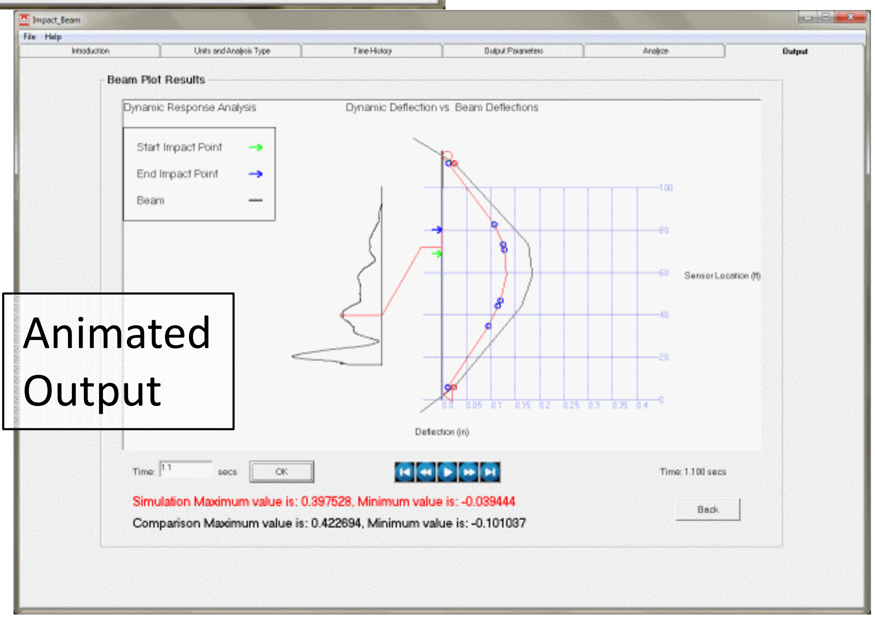
Impact_Beam

The flexibility of the impact beam provides energy absorption capability.

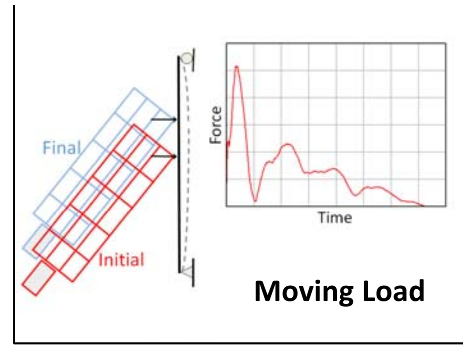
Impact_Beam *software provides a means to compute the dynamic structural response of a simply-supported flexible beam during various barge train impact events.*



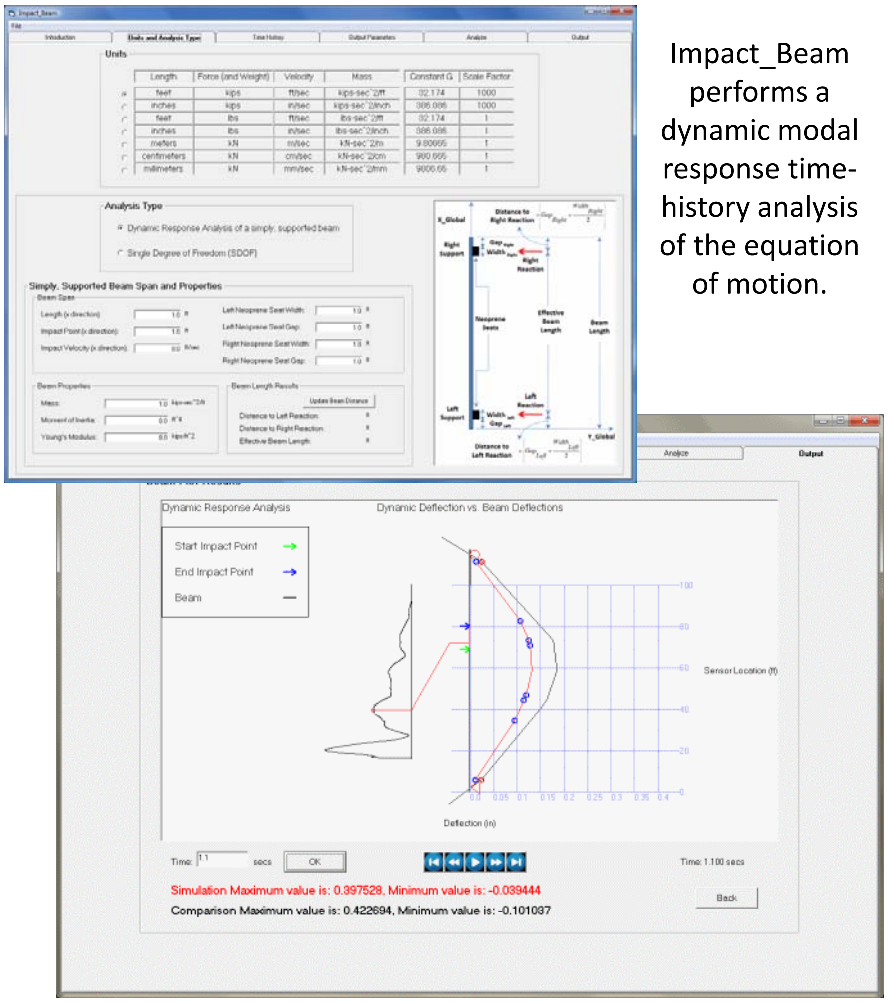




Dynamic Response of Winfield Simply-Supported Flexible Approach Wall



PC-based Software **Impact_Beam**

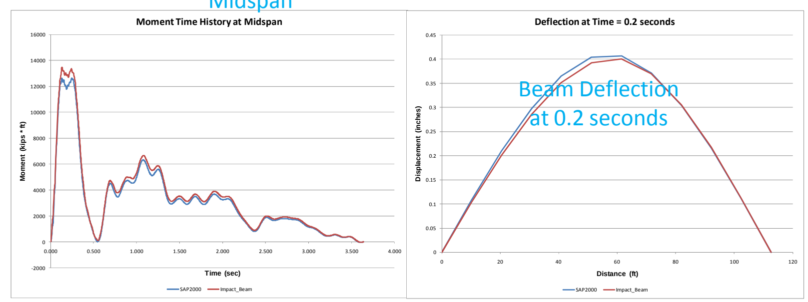


Impact_Beam performs a dynamic modal response time-history analysis of the equation of motion.

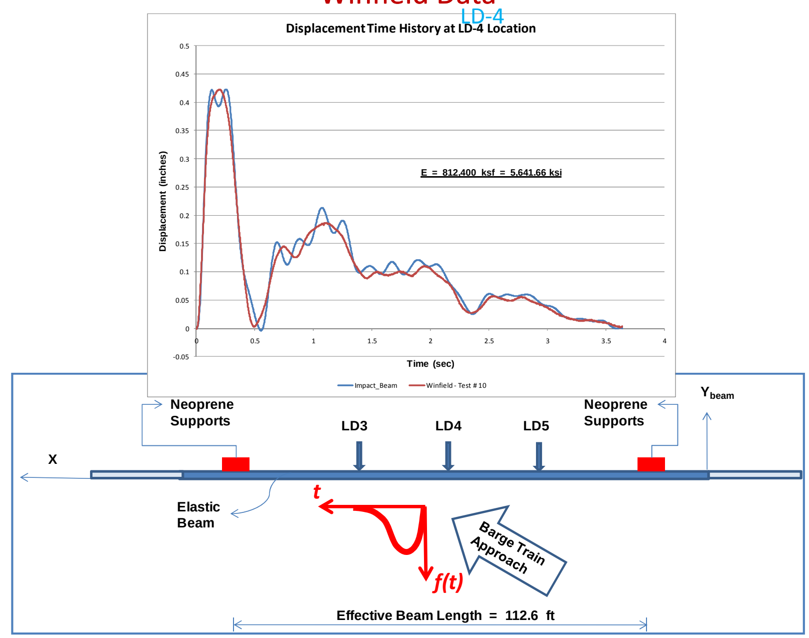
Validation

Midspan

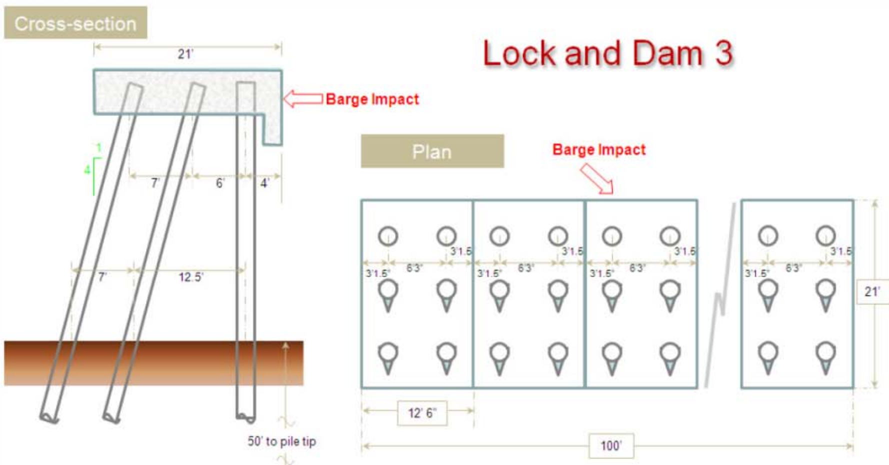
SAP-2000

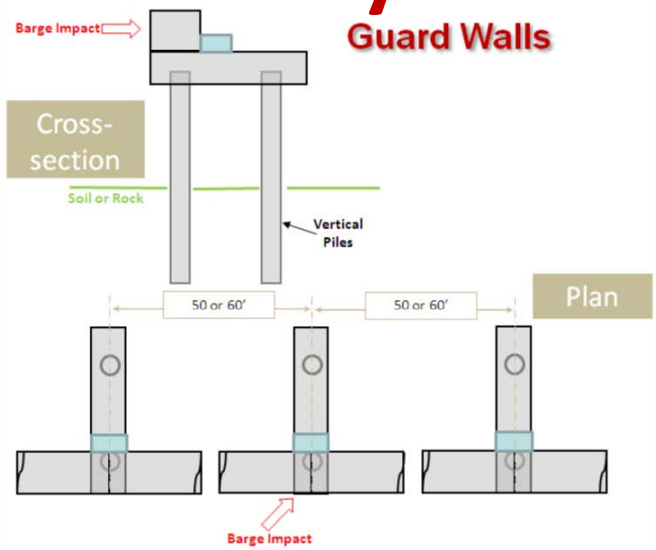


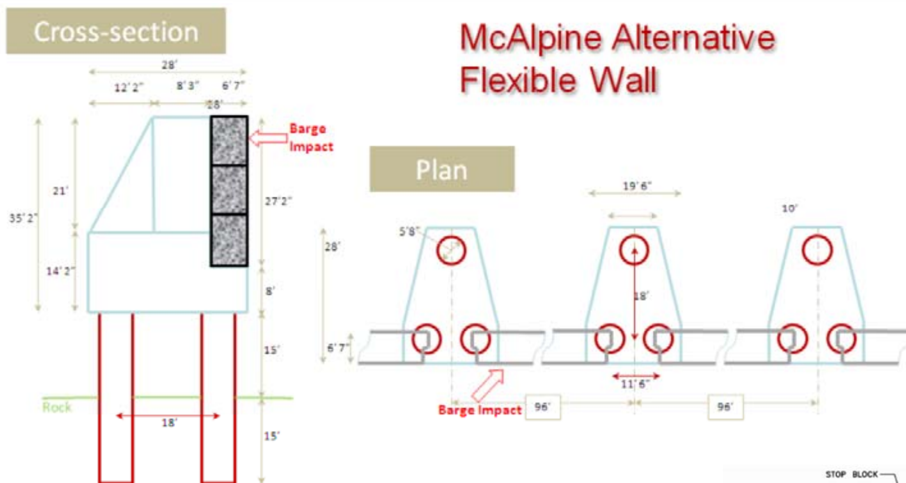
Winfield Data

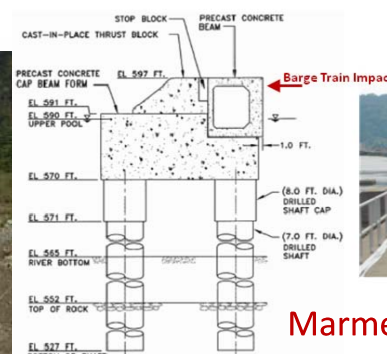


Pile-Founded Flexible Approach Wall Systems



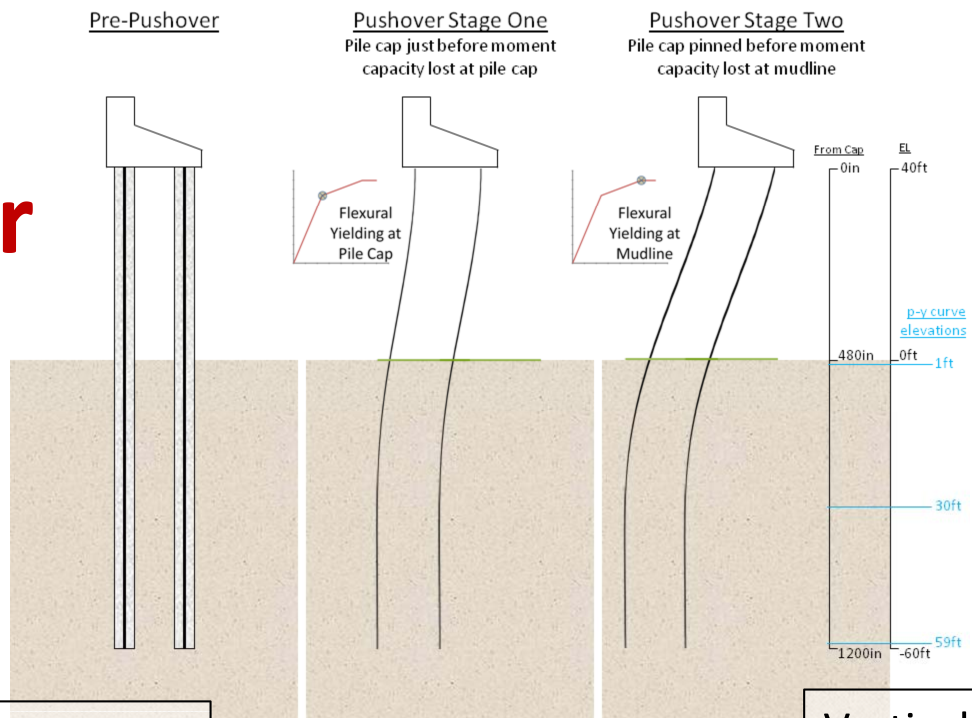


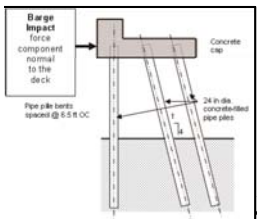




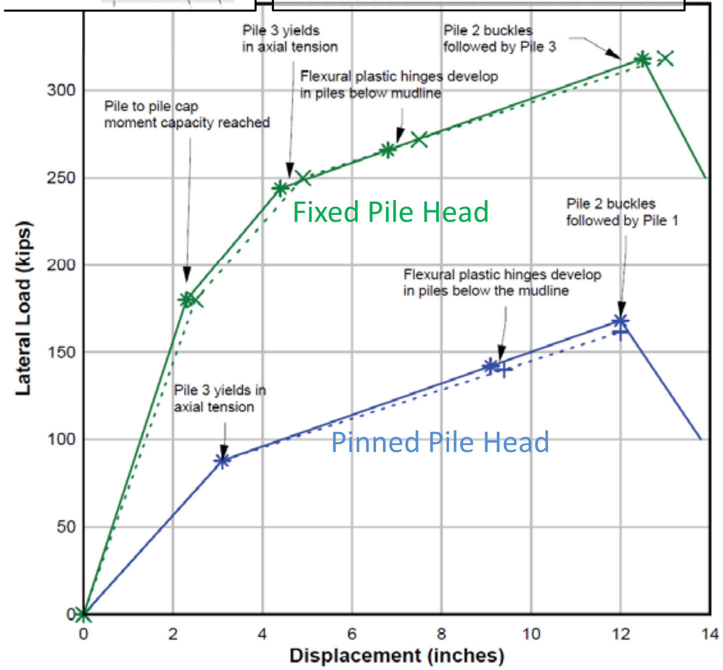
Marmet Pile Founded Wall

Pushover Analysis





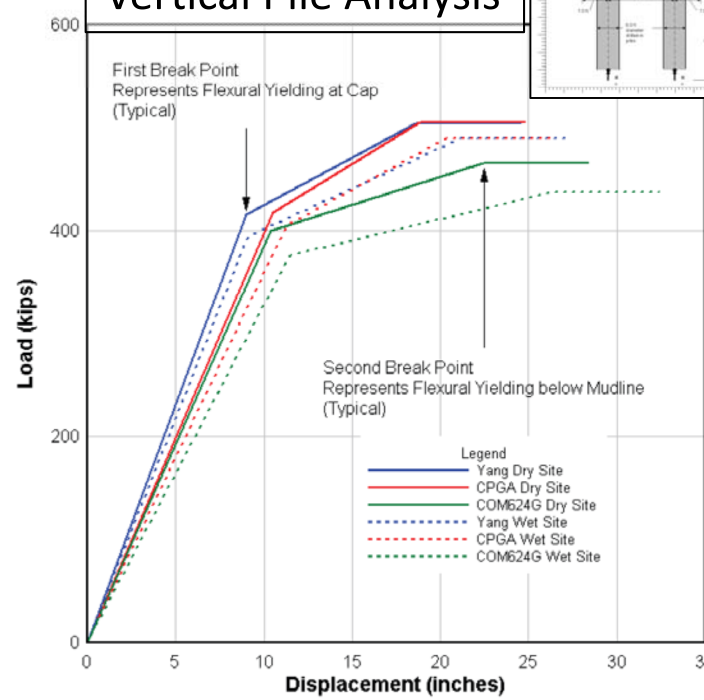
Batter Pile Analysis

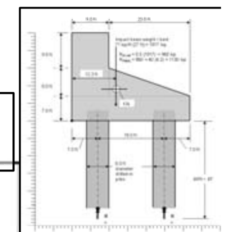


A pushover analysis is performed on a clustered pile group to:

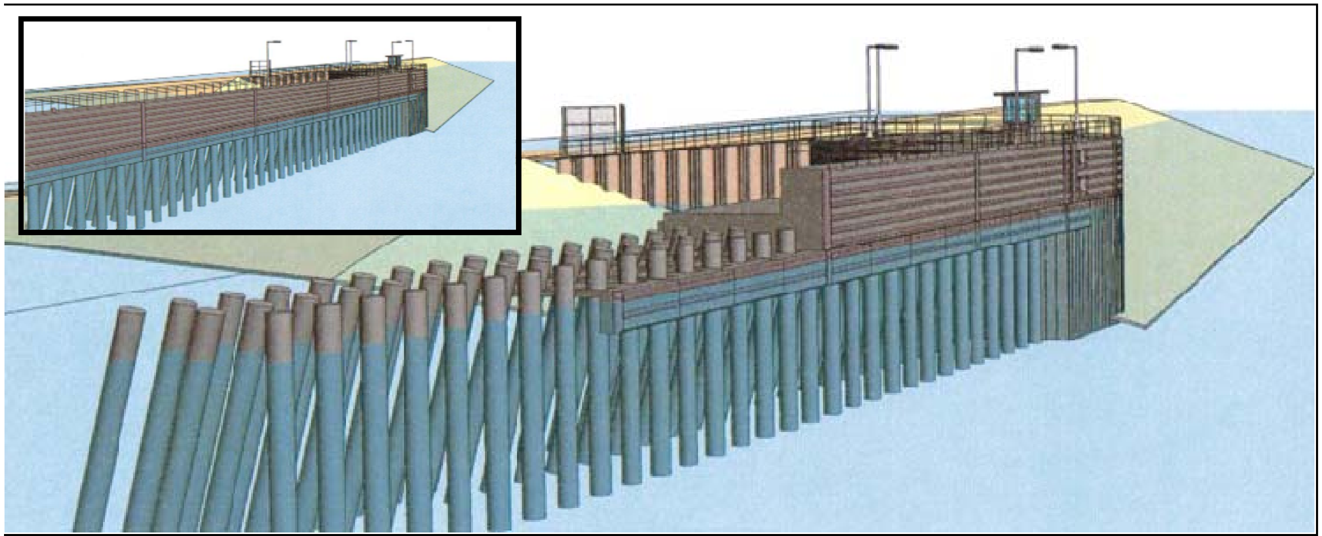
- *Establish the potential energy absorption capacity and the displacement of the pile group.*
- *Provides the non-linear force-deflection (spring) model of an individual clustered pile group for use in static or dynamic analysis of approach wall models (Impact_Deck, etc.)*

Vertical Pile Analysis

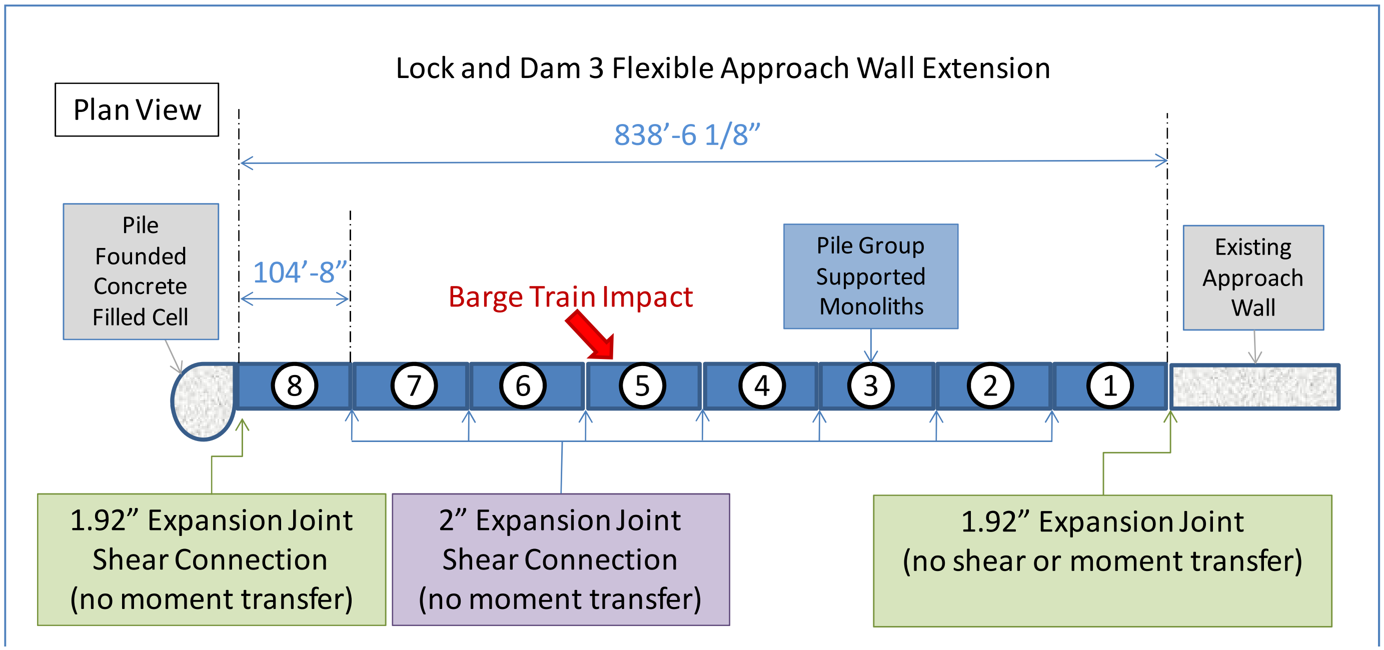


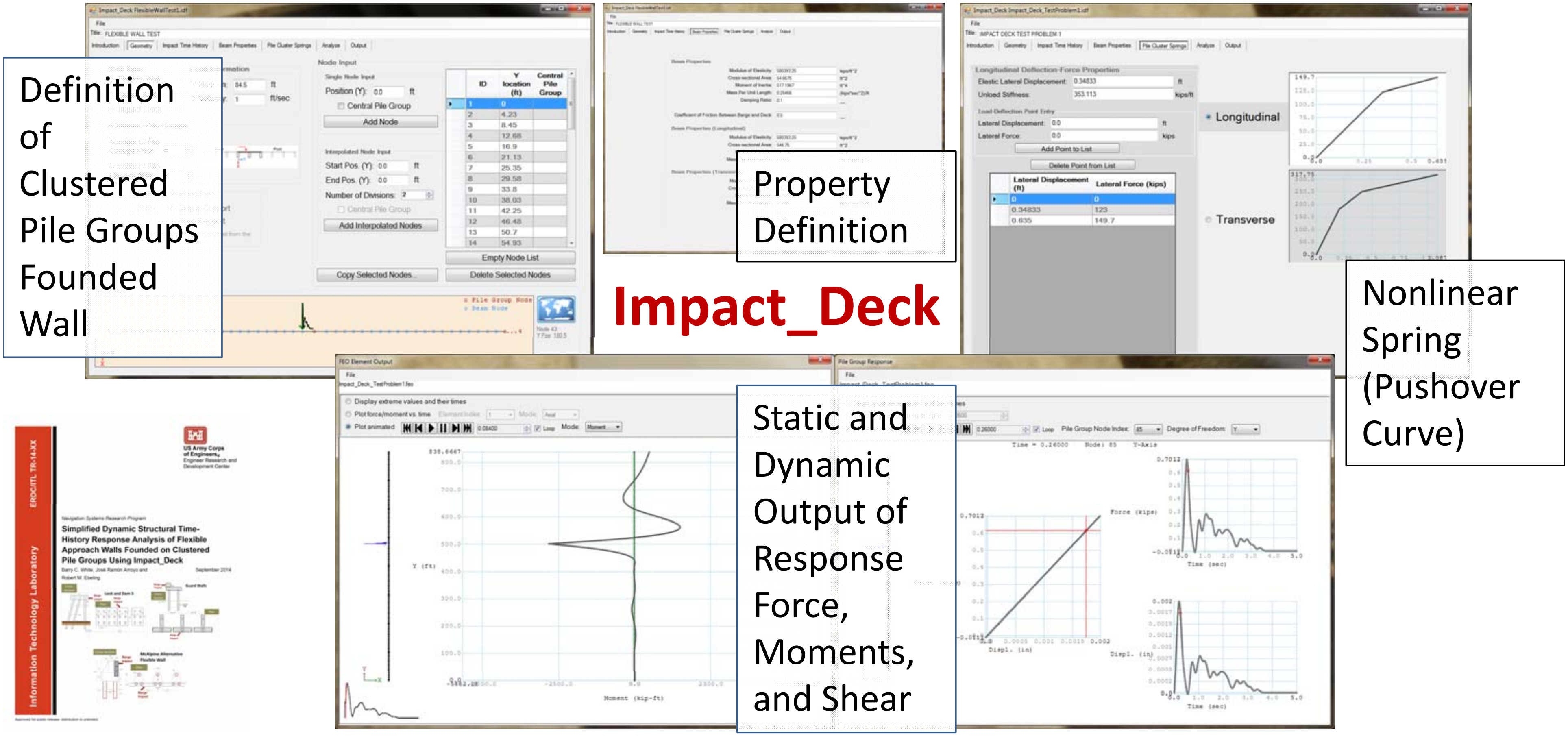


Load Sharing for an Impact Deck Founded on Clustered Pile Groups with Batter Piles

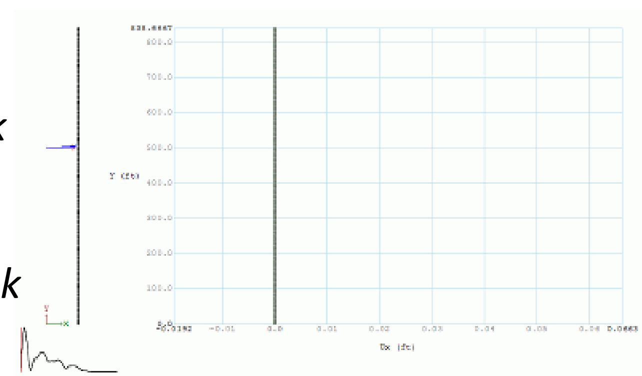


Each of the 8 deck monoliths is supported by 16 clustered pile groups



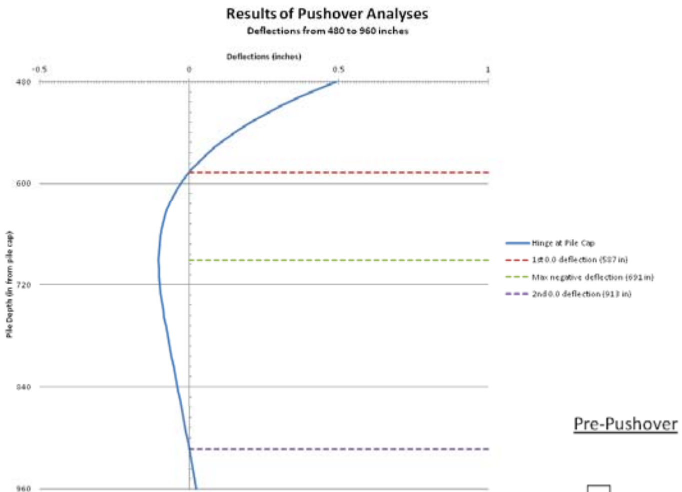


- Load sharing between clustered pile groups
  - *Individual pile group clusters carry only a fraction of the total impact load (e.g., Lock and Dam 3)*
- Dynamic Structural Response is important
  - *The total response peak force is greater than the input peak force*
  - *A phase lag exists between time-based response of pile groups and the applied impact load; The total response peak force occurs at a different time than the input peak force.*



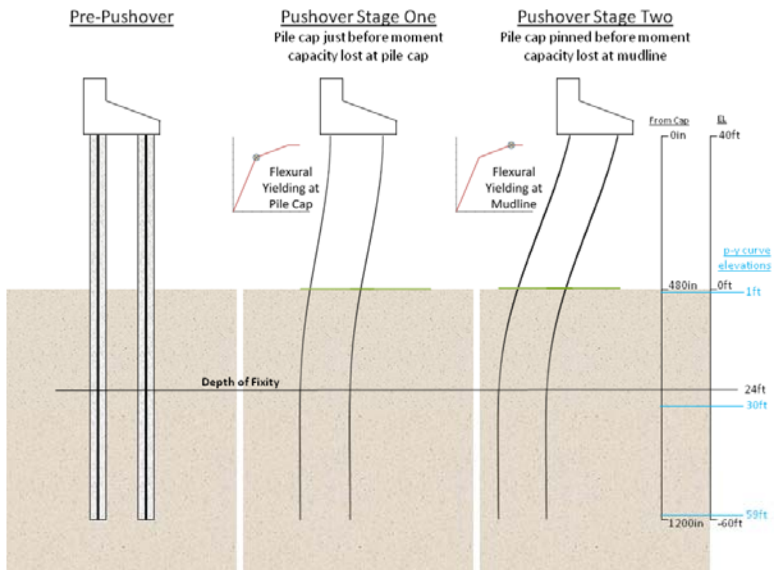
Using a Pushover Analysis
To Determine

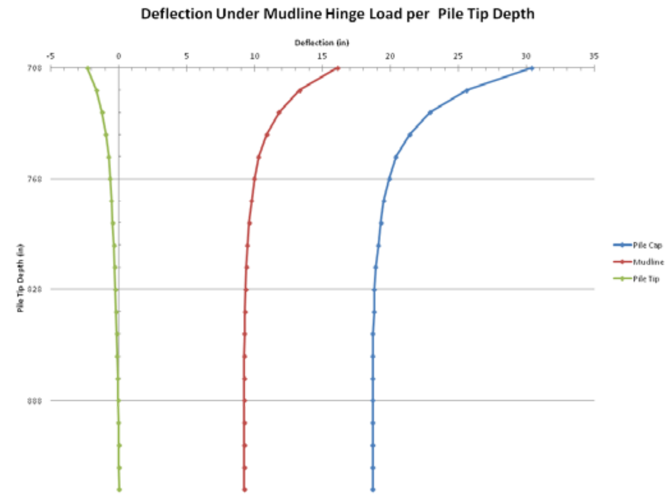
Depth of Embedment



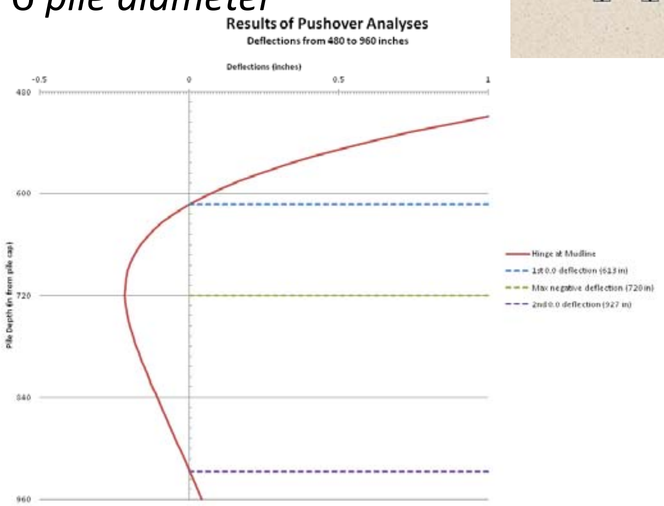
Research revealed a handful of methods to provide a "rule of thumb" estimate for the depth of embedment (fixity) of piles based on:

- *deflection points*
- *peak value points*
- *pile diameter*

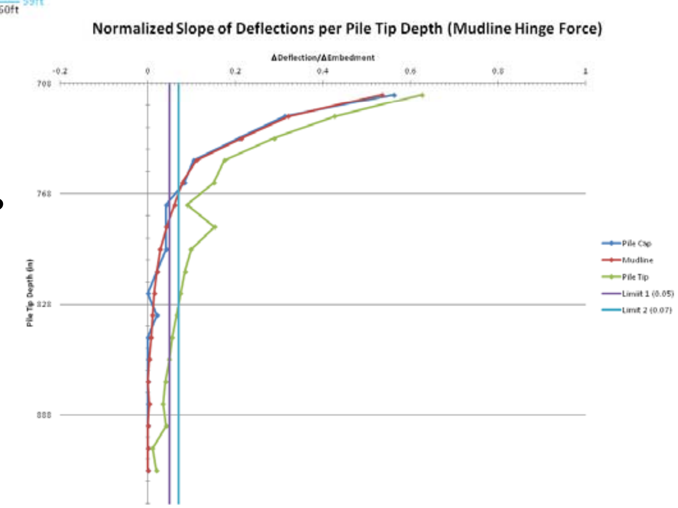




Our analysis reveals that an asymptotic relationship exists for pile cap deflection versus pile tip depth. Constraints can be placed to provide a **quantitative** *(as compared to qualitative) determination of fixity for a pile.*



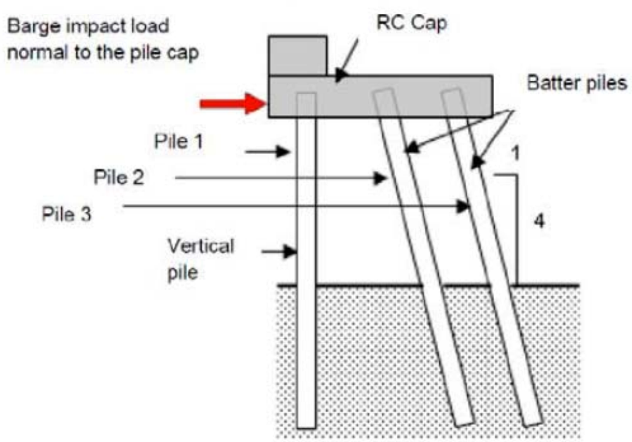
We are developing limits for the slope of the asymptotic deflection curve to quantitatively minimize depth of embedment and guarantee a level of fixity in order to reduce cost.



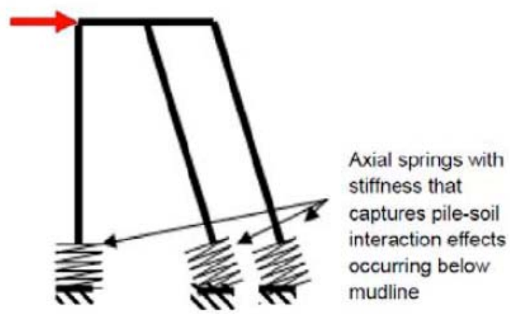
Pile-Founded Flexible Approach Walls

Finite Element Models are being used to determine deformations and terms for axial stiffness related to batter piles

Lock & Dam 3 Flexible Approach Wall Extension



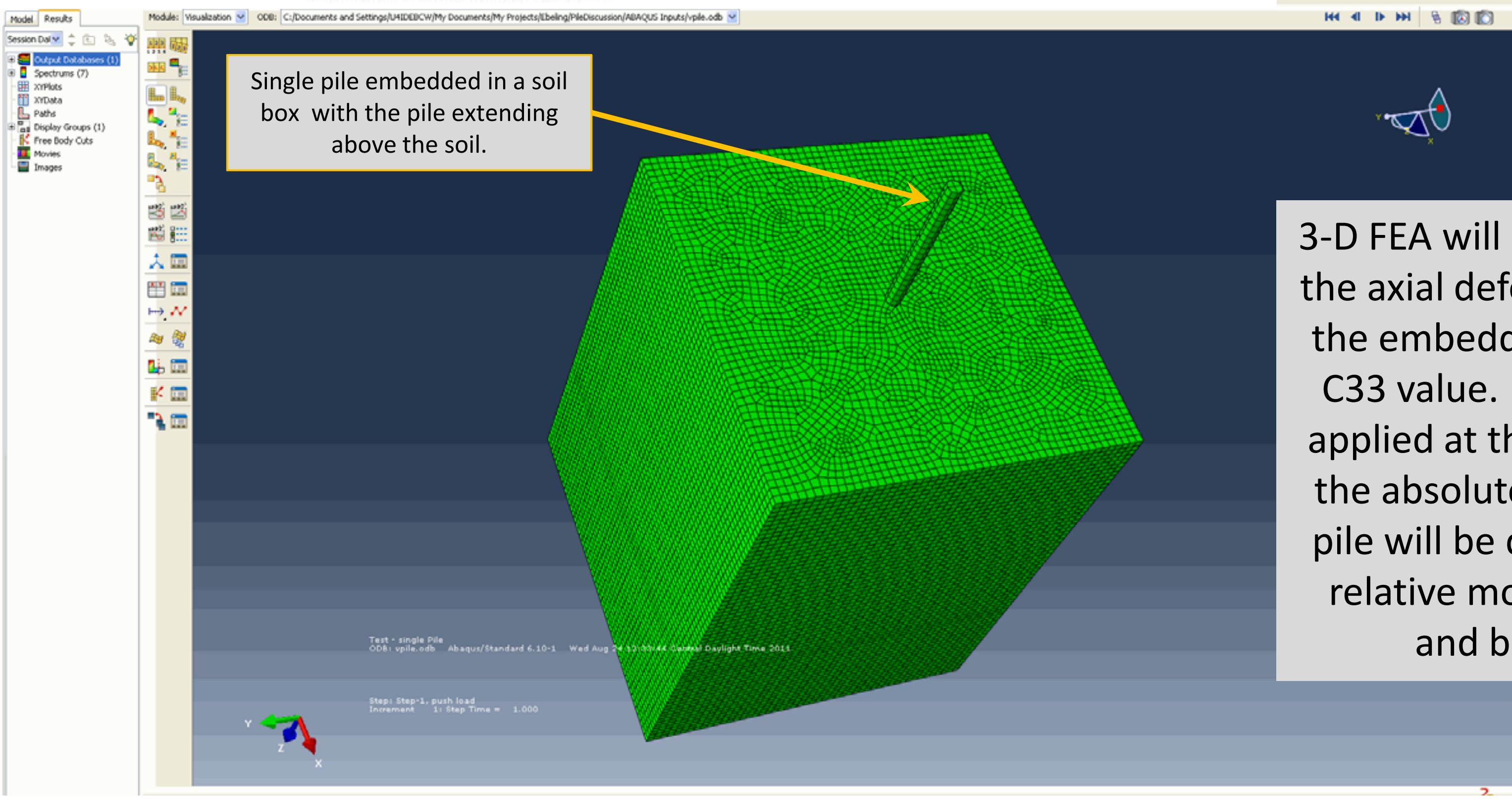
Simplified CPGA Pile-to-Soil Interaction idealization



C_{33} is the scale factor for the relative axial stiffness in soil (with a large impact on batter piles):

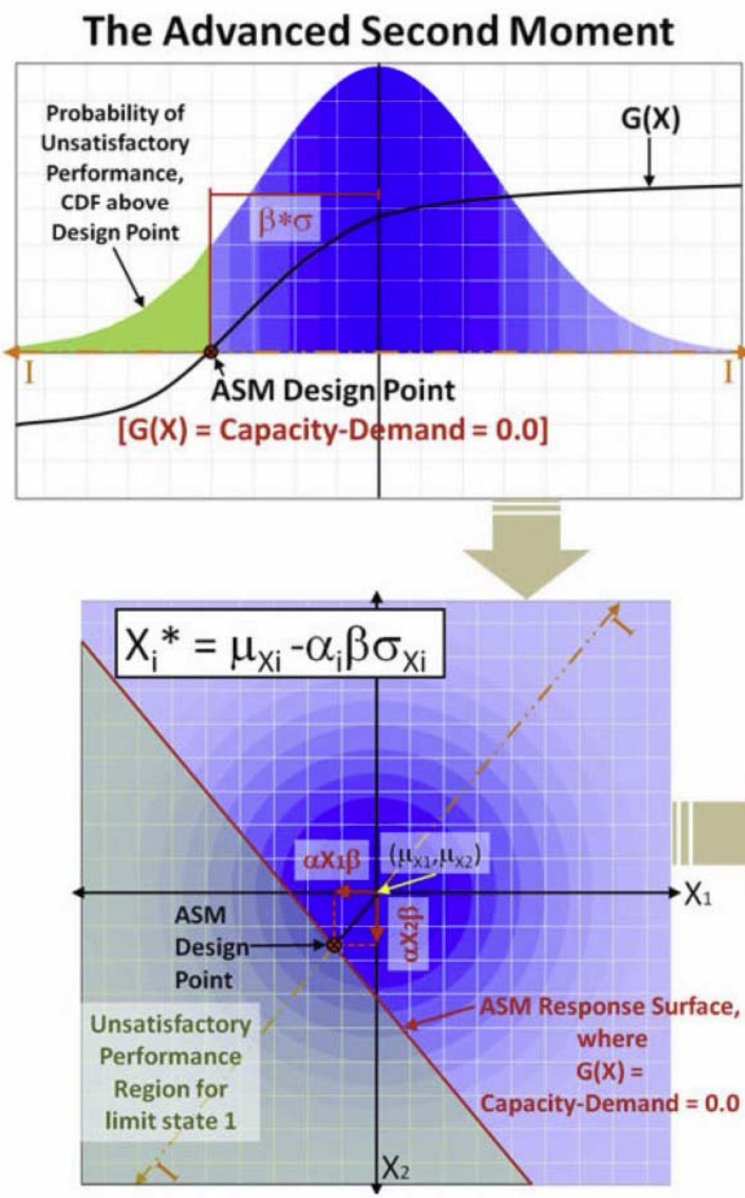
$$C_{33}*AE/L_e = b_{33}$$

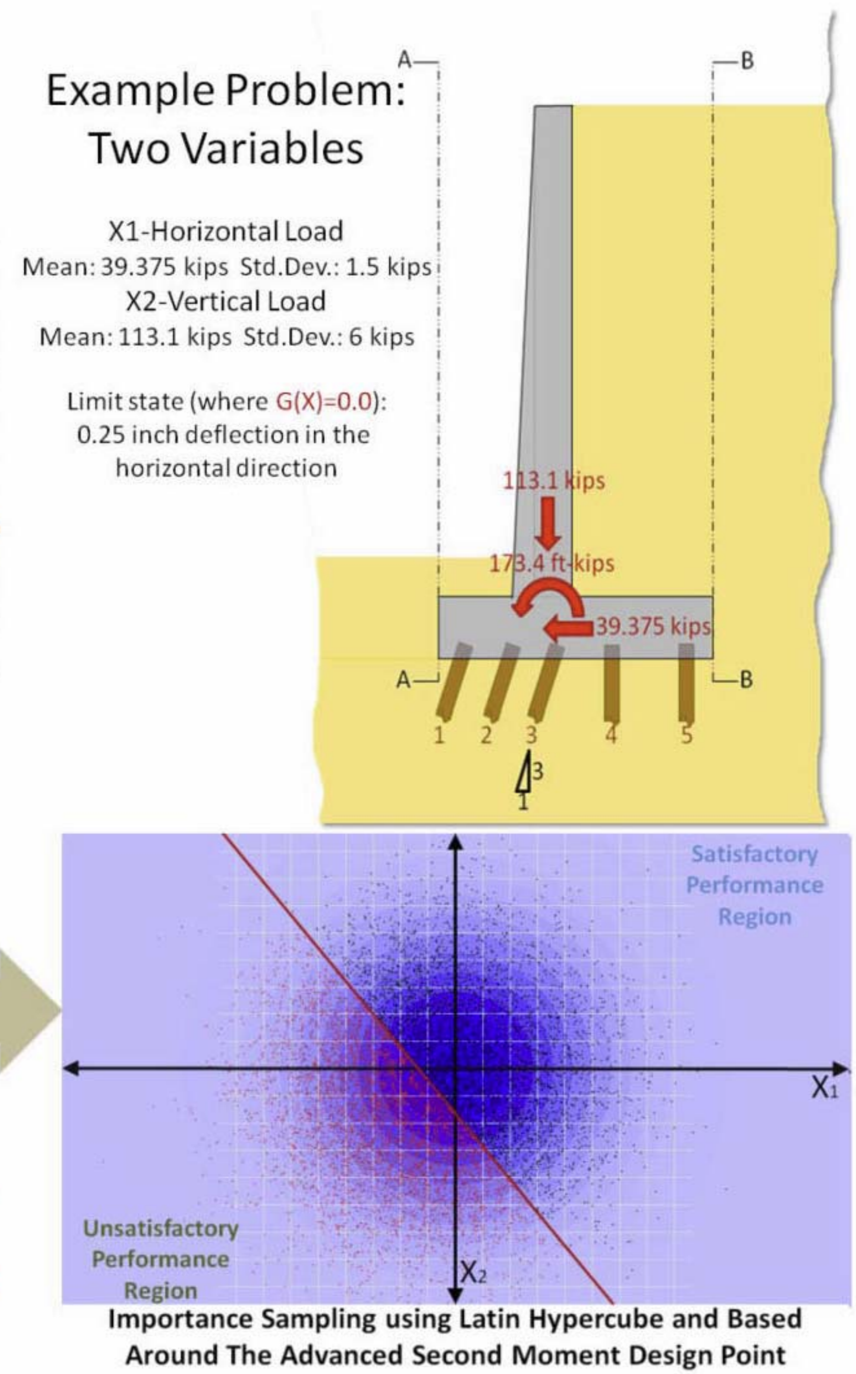
An axial load is applied to the pile and the deflection of the pile can be computed for the soil regime.

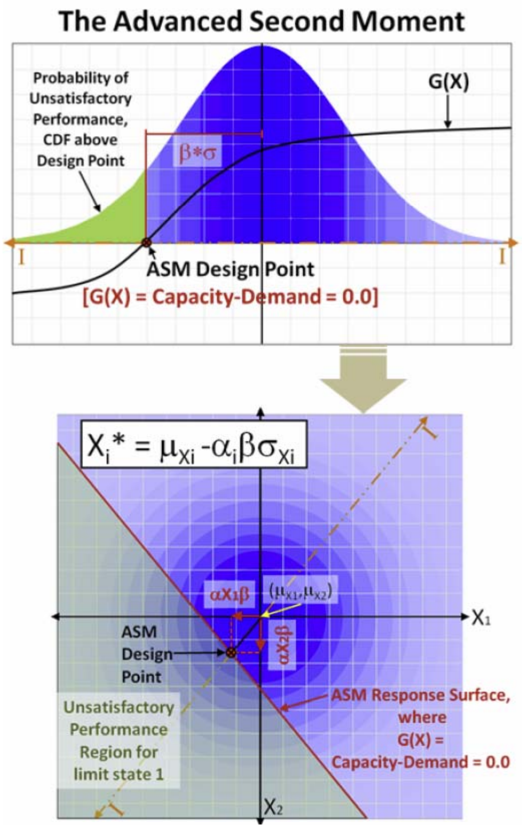


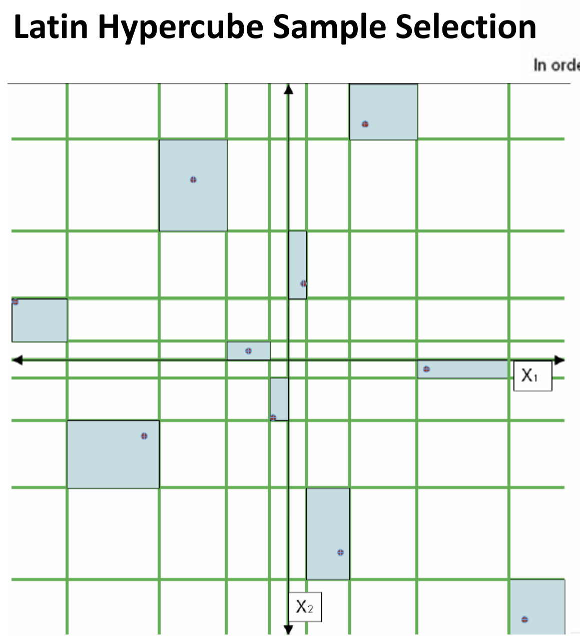
3-D FEA will be used to determine the axial deformation response of the embedded pile to define the C33 value. An axial load will be applied at the top of the pile and the absolute deformation of the pile will be determined from the relative movements at the cap and base of the pile.

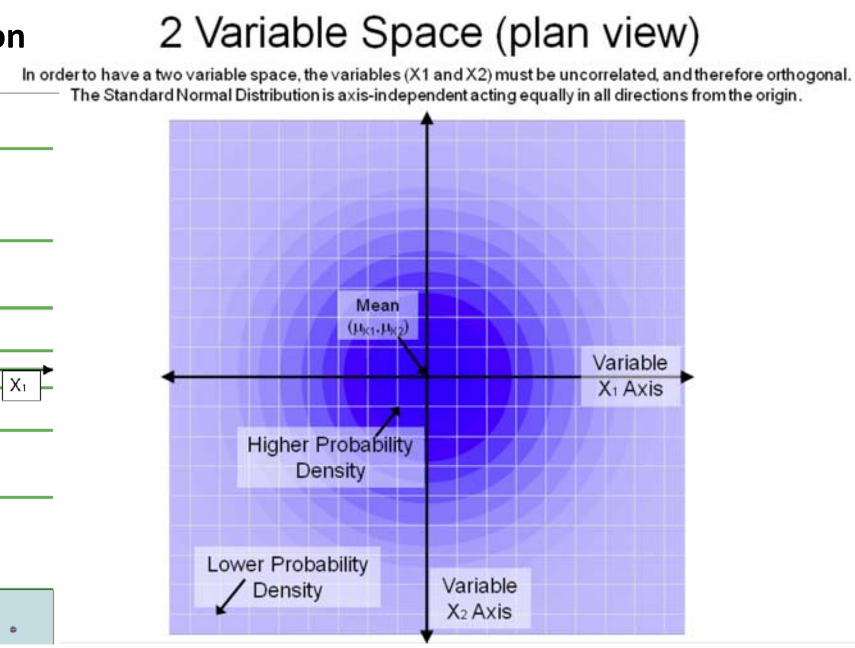
CPGA-R *Pile Group Reliability Analysis*





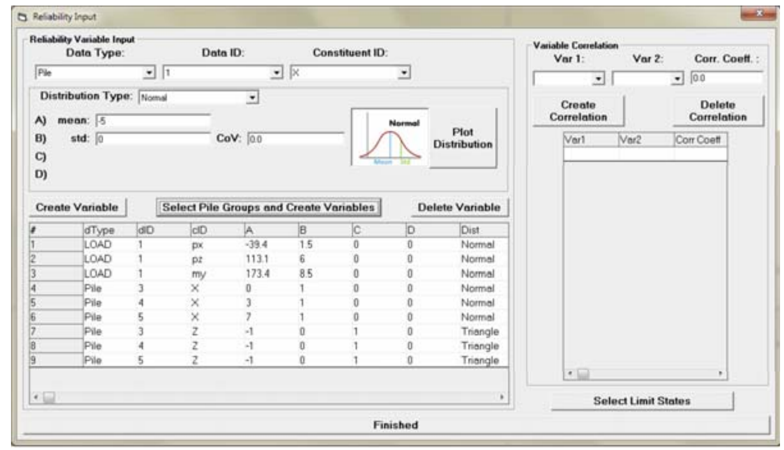


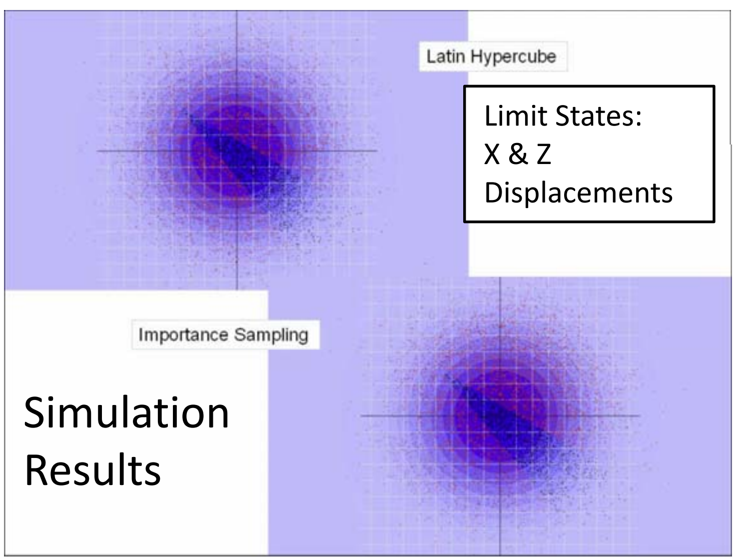




CPGA-R

Additional GUI Inputs





•Provides the capability of Reliability Analysis of pile founded hydraulic structures for use in Major Rehabilitation studies.

•Computes the Probability of Unsatisfactory Performance (PUP).

•Computes a PUP value using Importance Sampling simulation method with efficient Latin Hypercube sampling guided by the Advanced Second Moment method to focus the center of simulation.

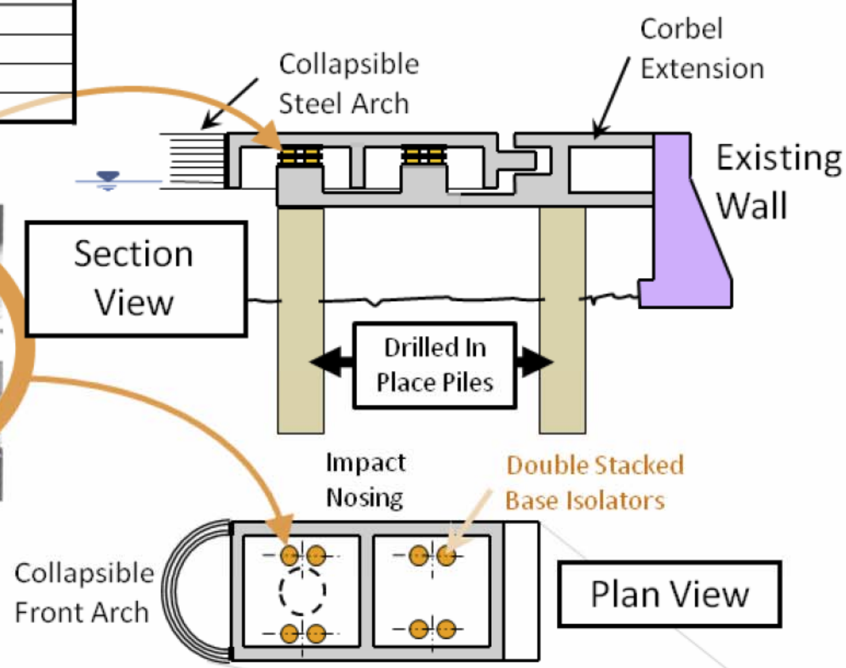
•Maintains all the Deterministic capabilities of CPGA

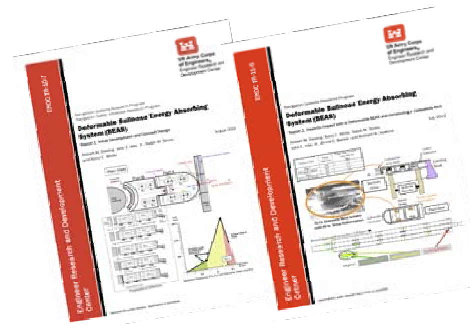
Deformable Bullnose Energy Absorbing System (BEAS)

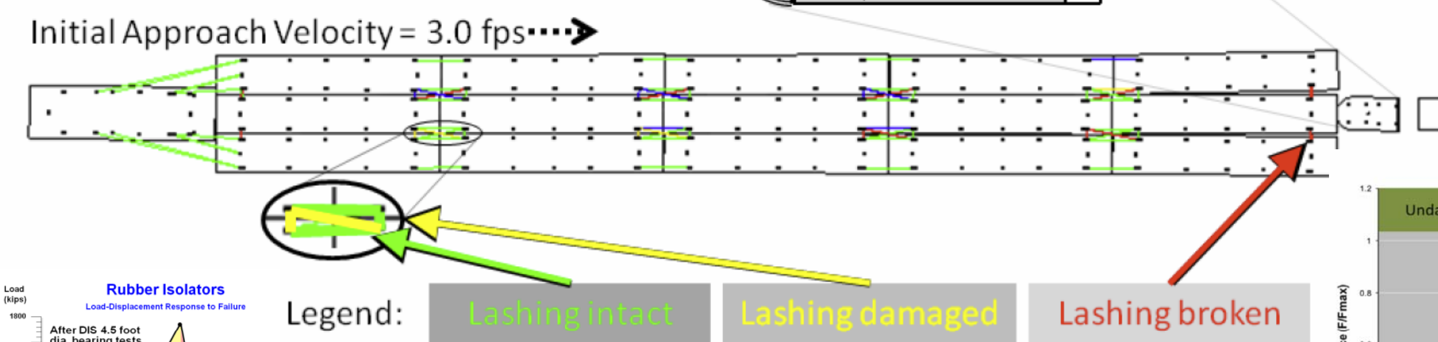
Bullnose Type	Barge Train Size	Barge Train Integrity Limit Velocity (fps)
Rigid	3x5	3.3
Deformable BEAS	3x5	4.5
Rigid	3x4	3.0
Deformable BEAS*	3x4	4.7

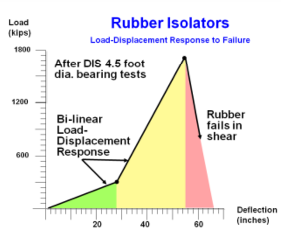
* with Collapsible front arch

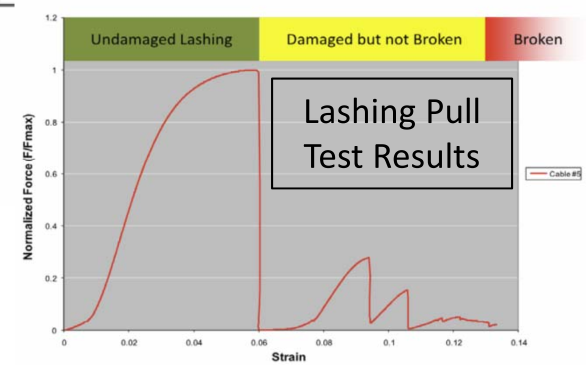
51 in. Diameter Base Isolator with 40 in. Shear Deformation









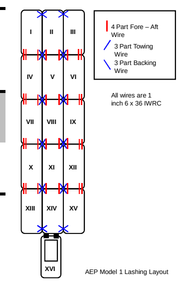


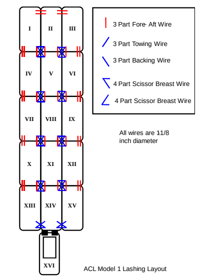
Alternative designs for the collapsible front arch (using double super cone fenders) allow head-on impacts of up to 6.1 fps for a fully ballasted 3x5 barge train while maintaining barge train integrity

Deformable BEAS Limiting Velocities

Lashing Layout Comparison

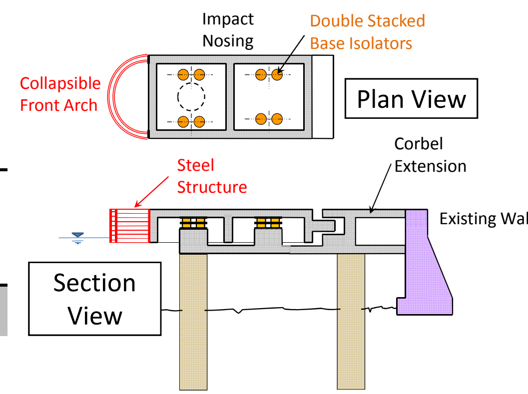
Barge Train Size	Velocity (fps)	Lashing Layout	Barge Train Integrity
3x5	2.7	AEP	Complete Loss
		ACL	Maintained





Rigid vs Deformable BEAS

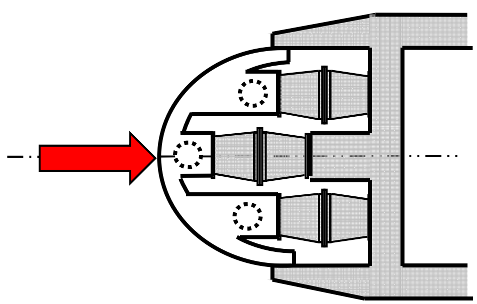
Barge Train Size	Deformable BEAS Configuration	Max Velocity to Maintain Barge Train Integrity (fps)
3x5	Rigid	**3.3**
	8 Double-Stacked Reduced Stiffness	**4.5**



Collapsible Front Arch

Barge Train Size	Deformable BEAS Configuration	Max Velocity to Maintain Barge Train Integrity (fps)
3x4	Rigid	**3.0**
	8 Double-Stacked Reduced Stiffness	**4.7**

Preliminary Double Super Cone Front Arch Results



Barge Train Size	Number of Double Super Cones	70" Deformation Force (kips)	Peak Calculated Force (kips)	Impact Nosing Deflection (ft)	Max Velocity to Maintain Barge Train Integrity (fps)
3x4	5	4,000	5,003	6.66	6.2
	6	4,800	4,148	6.42	**6.1**
	7	5,200	n/a	n/a	<5.5