3-D Assessment of a T-wall System in New Orleans

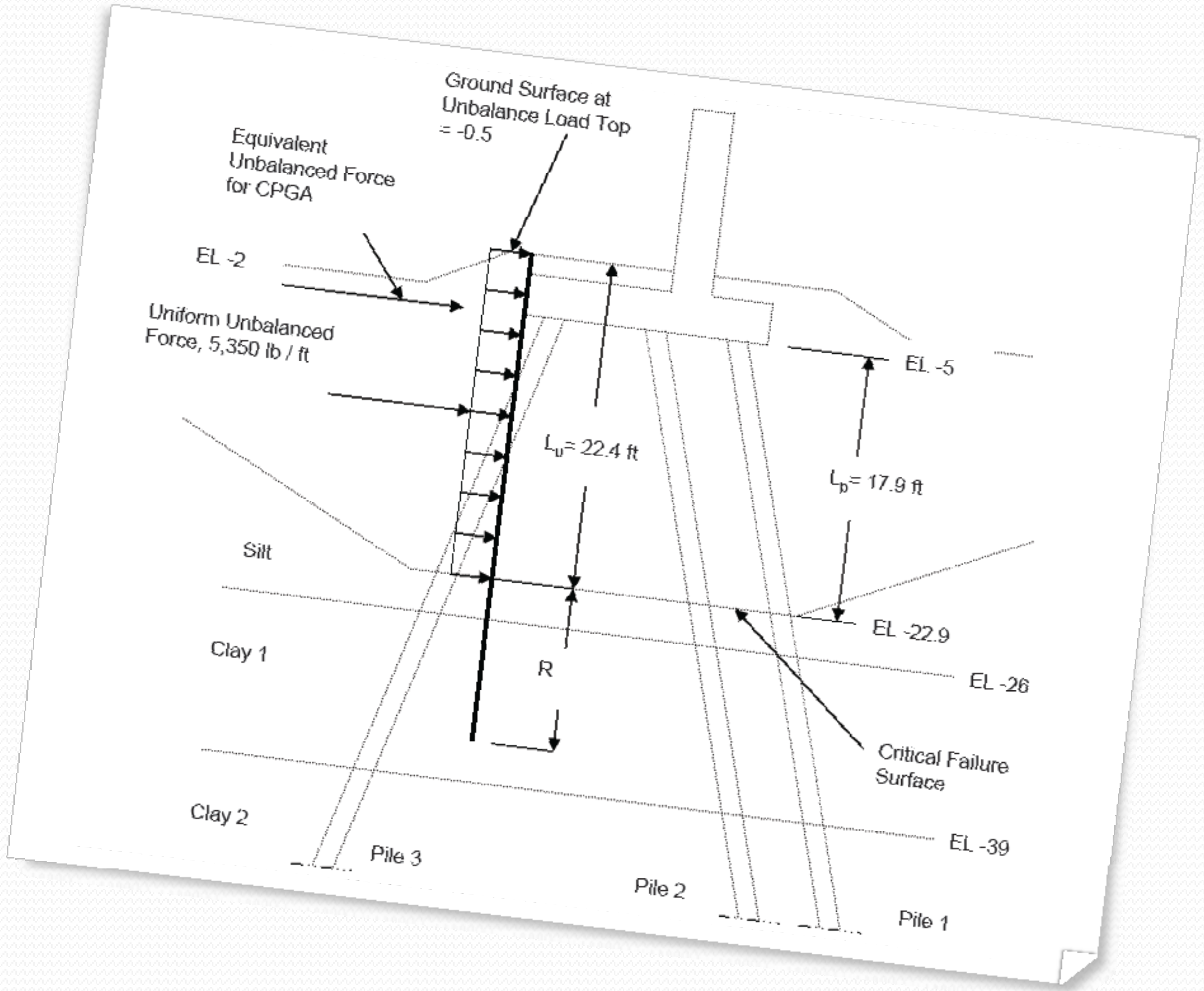
Jinoh Won*, Chung R. Song**, Sudarshan Adhikari**, Alexander H.-D. Cheng** and A. Al-Ostaz**

*: Samsung Construction Co. Ltd. Seoul Korea
**: University of Mississippi, University, MS 38655

Motivation

- **T-walls survived Hurricane Katrina.**
- **Are T-walls truly survived and barely survived?**
- **Need sophisticated analysis of T-wall.**
- **Conducted 3-D numerical analysis for T-walls in IHNC, New Orleans.**

Typical T-wall section

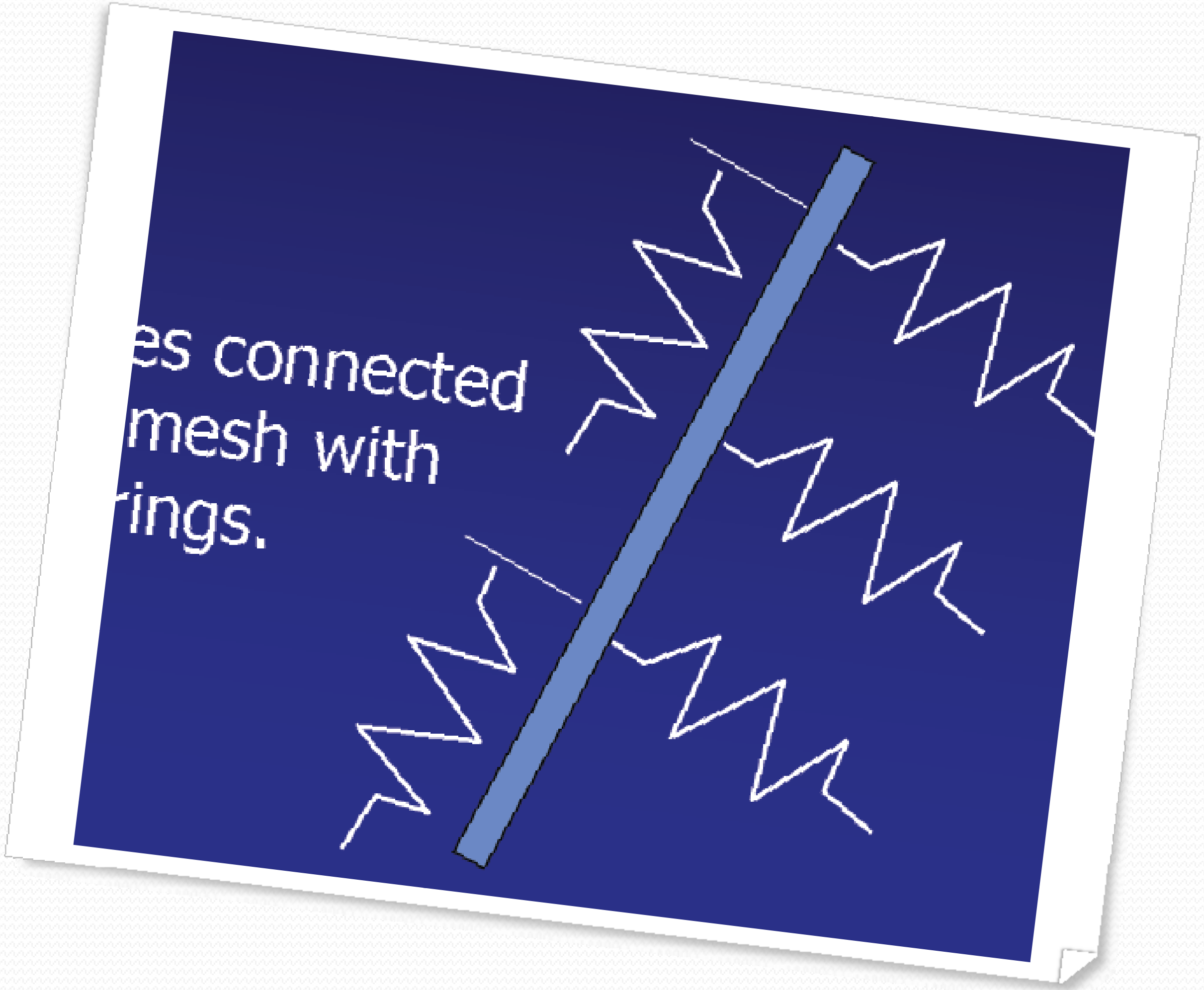


Current Design methods

(Hurricane and Storm Damage Reduction System Design Guidelines, May 2008)

- **Uncoupled analysis**
- **Slope stability** analysis
  - Check Factor of Safety: UTexas4, Slope/W
  - Find “Unbalanced Load”
- **Pile Group** analysis
  - Preliminary design with CPGA – check flow through
    - Calculate pile head loads, cap displacement
  - “Group 7 Analysis” of critical cases
- Developed to match with the 2D FLAC analysis results

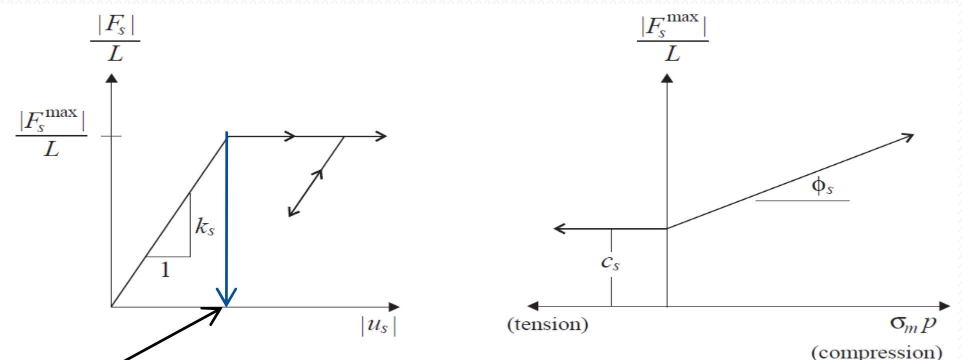
3. Pile structural element in FLAC 3D



SELs

- We could model everything with zones
- Zone are poor at modeling bending (a large number may be required across the thickness)
- Grid generation becomes problematic when modeling structures with zones (geometric problems as well as RAM shortage)
- If we are not interested in small scale local effects (e.g. detailed stress distribution across an oddly shaped beam section) then SELs are ideal.

How to estimate shear coupling spring constants?



(a) shear force/length versus relative shear displacement, u_s

(b) shear-strength criterion

$$\frac{|F_s^{max}|}{L} = c_s + \sigma_m \cdot \tan(\varnothing_s) \cdot A_s$$

0.03B for sand
0.01B for clay

Alternative

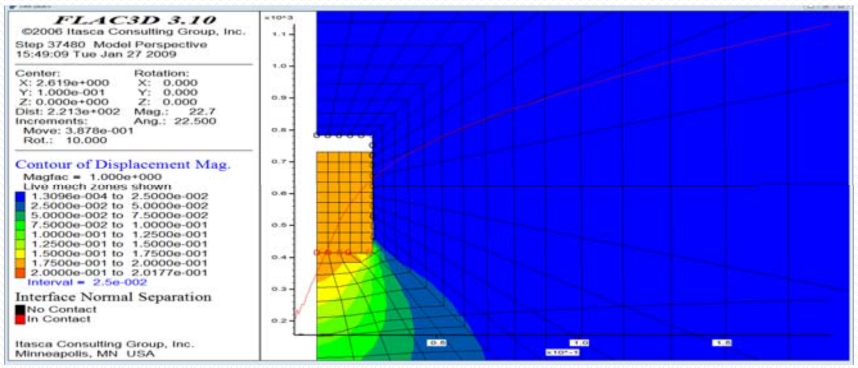
$$\frac{|F_s^{max}|}{L} = Q_s = f_s \cdot A_s$$

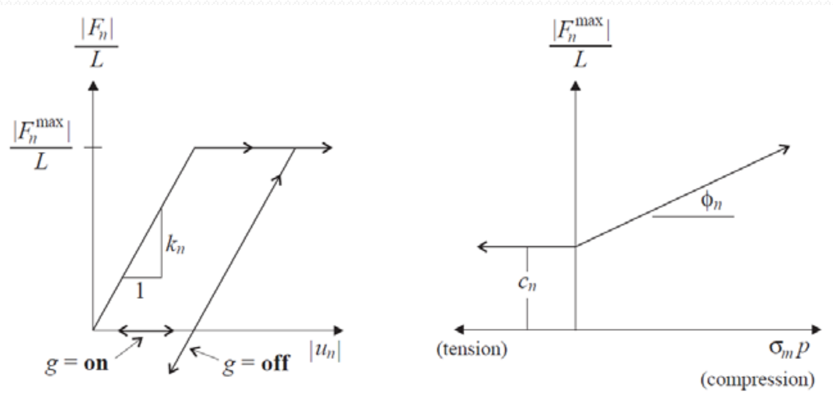
$f_s = \sigma_h \cdot \mu = (K_o \sigma_v)\tan(\delta)$ for sand

$f_s = \alpha \cdot s_u$ for clay

How to estimate normal coupling spring constants?

2D plane strain analysis

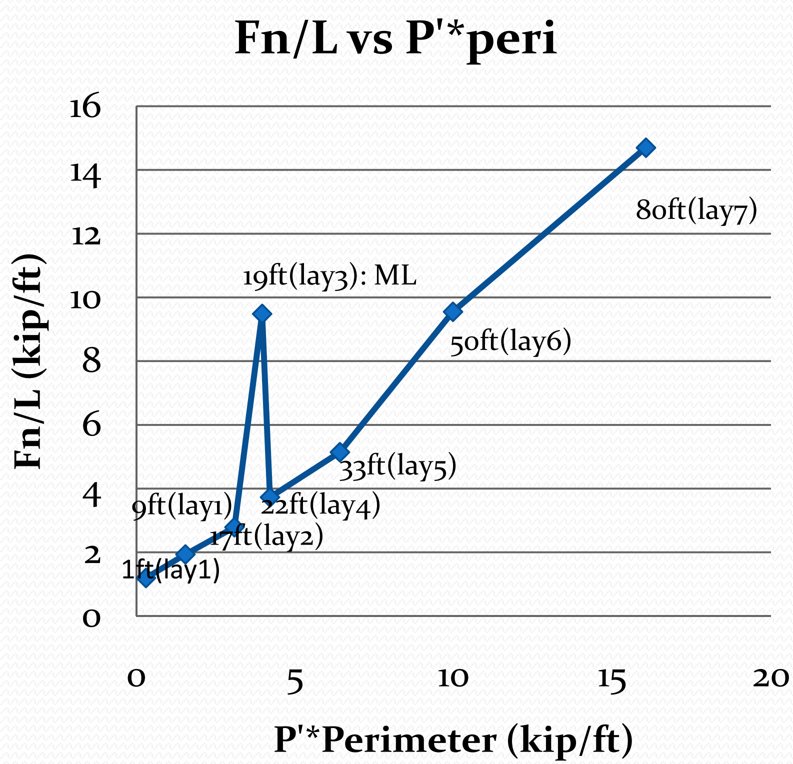




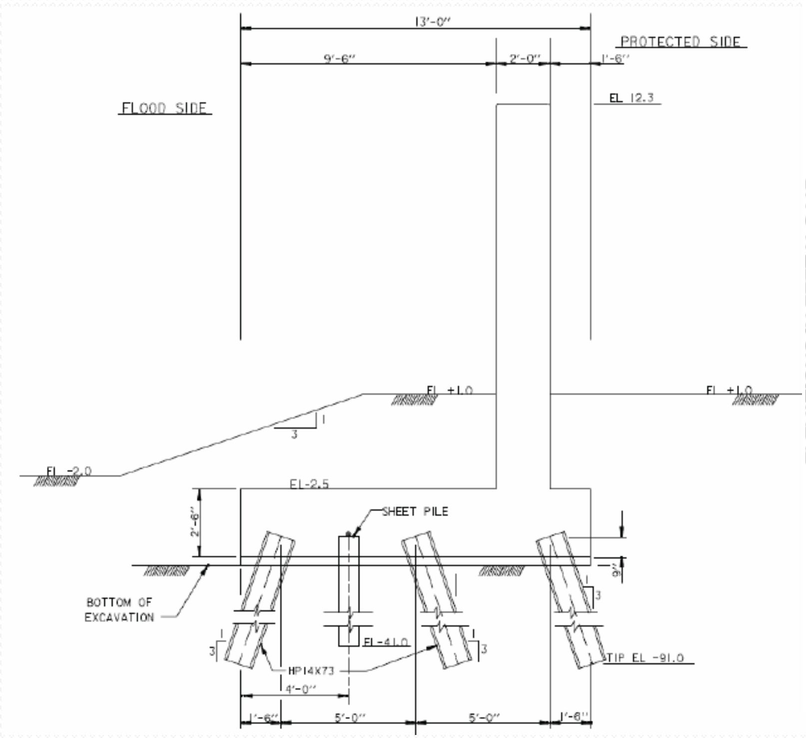
(a) normal force/length versus relative normal displacement, u_n

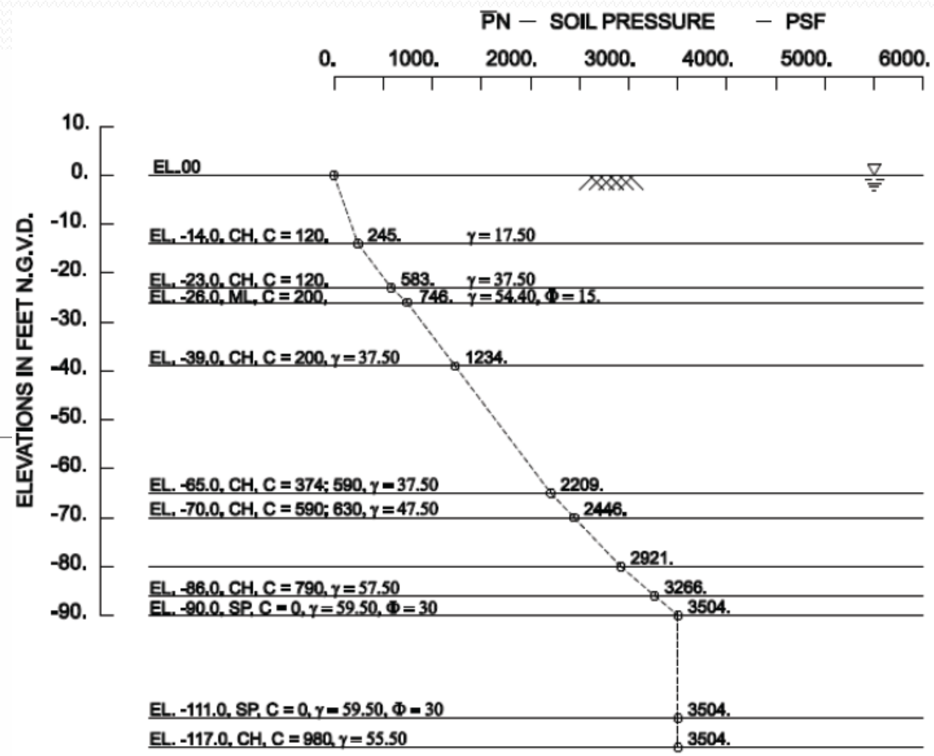
(b) normal-strength criterion

Estimate constants



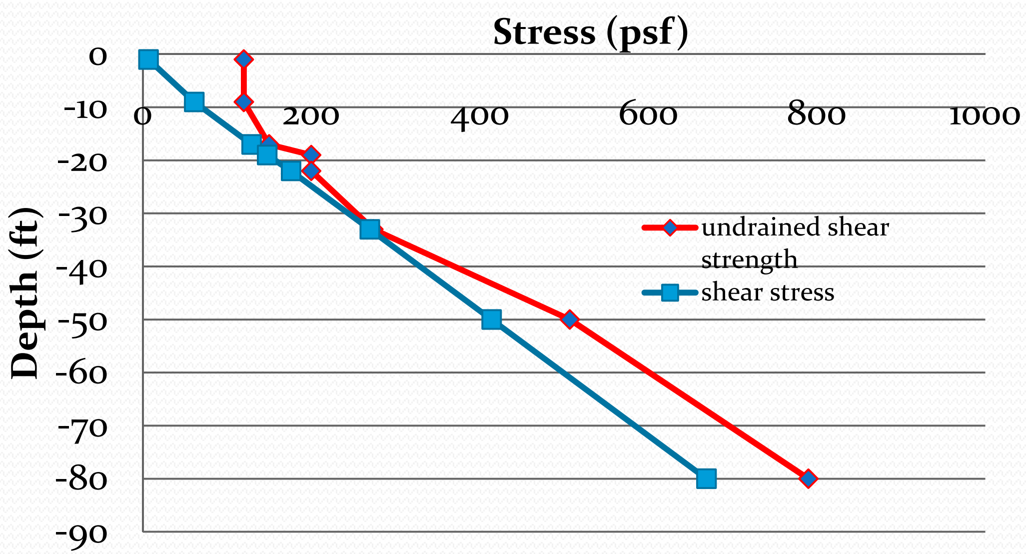
T-wall and ground conditions





Soil properties

								Modulus			
Layer #	top ELE	top Depth(ft)	Soil type	**c (psf)**	c_inc (psf/ft)	ϕ	γ (pcf)	E (psf)	G/s_u	**G (psf)**	**K (psf)**
1	-5	0	CH	120			80		100	1.20E+04	2.96E+05
2	-14	9	CH	**150**			100		130	1.95E+04	4.81E+05
3	-23	18	ML	200		15	117		130	2.60E+04	6.41E+05
4	-26	21	CH	200			100		130	2.60E+04	6.41E+05
5	**-31**	26	**CH**	**217**	**8.1**		**100**		**130**	**2.82E+04**	**6.96E+05**
6	**-39**	34	**CH**	**374**	**8.3**		**100**		**160**	**5.98E+04**	**1.48E+06**
7	-70	65	CH	790			100		160	1.26E+05	3.12E+06
8	-86	81	SP			30	115	4.23E+05		1.63E+05	3.53E+05
9	-111	106	CH	980	8.3		115		160	1.57E+05	3.87E+06



Initial shear stress
& undrained shear strength

Pile properties

[For Solid element]

HP 14*73

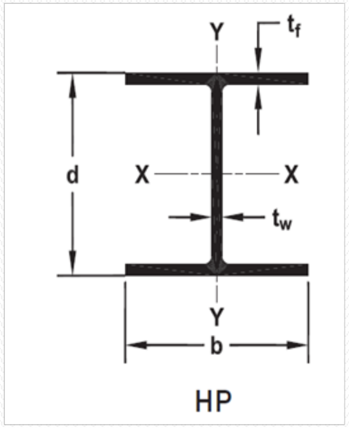
E_steel=	4.18E+09	psf
Iy=	0.035156	ft4
Iy_solid=	0.14669453	ft4

Equivalent E

(Same EI)

E_eq=	1.00E+09	psf
nu=	0.3	
K=	4.77E+08	psf
G=	3.85E+08	psf

gamma_t=	139	pcf
density=	4.32	



E_eq ?
(EI=const.)

b = 1.22 ft
d = 1.12 ft

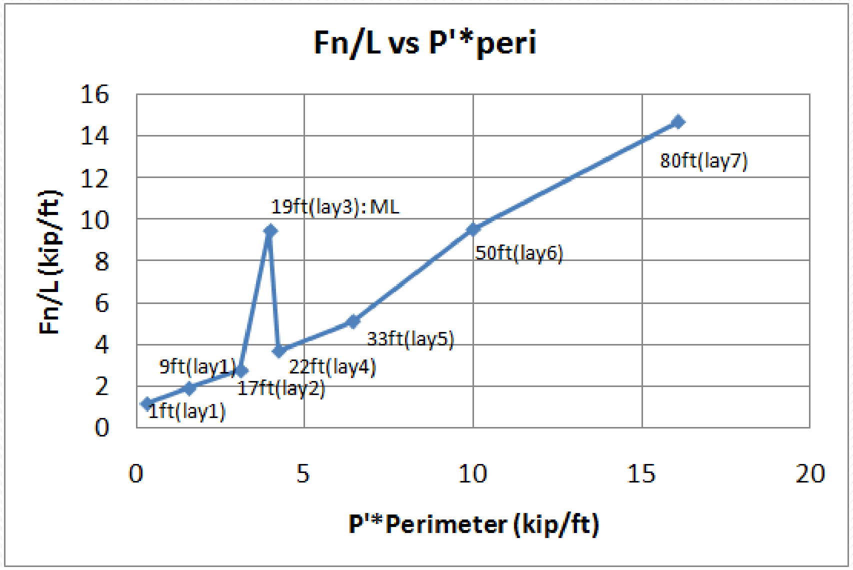
[For Pile element]

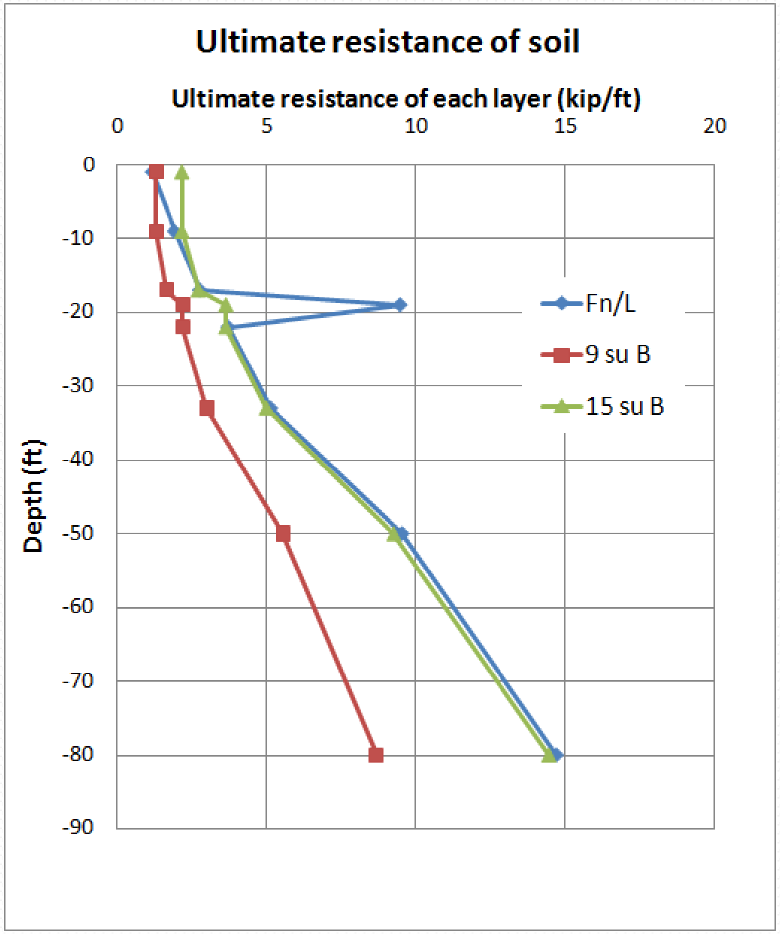
(HP14*73)

E (psf)	nu	XCArea	XCJ	Xciy	XCiz	Per
4.18E+09	0.3	0.1486	0.047743	0.01259	0.03516	4.699

Input parameters for pile element

(Normal coupling-spring constants)





* “cs_ncoh”, “cs_nfric” from upper graph

* For rectangular pile in clay,

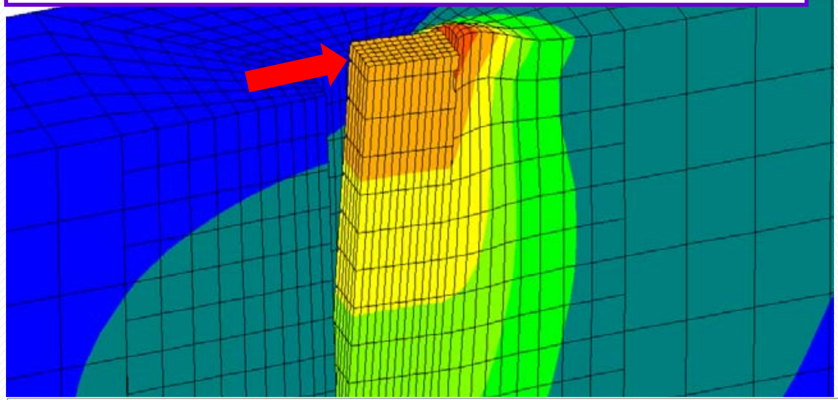
$$p_{ult} = 15 \cdot s_u \cdot B$$

Task 2B: T-Wall Analysis
Procedure to Define A Proper Pile Element

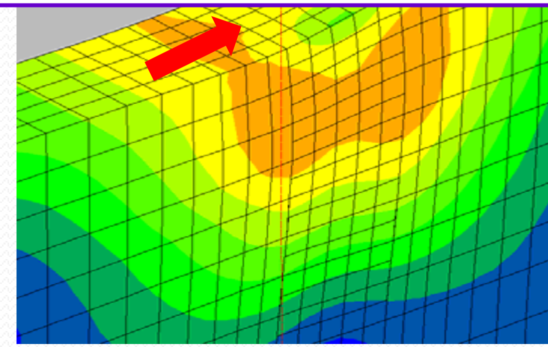
1. Perform full 3-D solid element simulation with piles embedded.
2. Apply active force or passive force to piles and compute stresses and strains.
3. From stresses and strains obtain P-y curves for multiple depths.
4. Using P-y curves, find proper soil-pile interaction spring constants and failure loads.
5. Using these soil-pile interaction spring constants and failure loads, perform 3-D simulation with "Pile Elements".
6. When the results of steps 2 and 5 are almost identical, then the pile element is properly defined.

T-Wall Analysis
Procedure to Define A Proper Pile Element

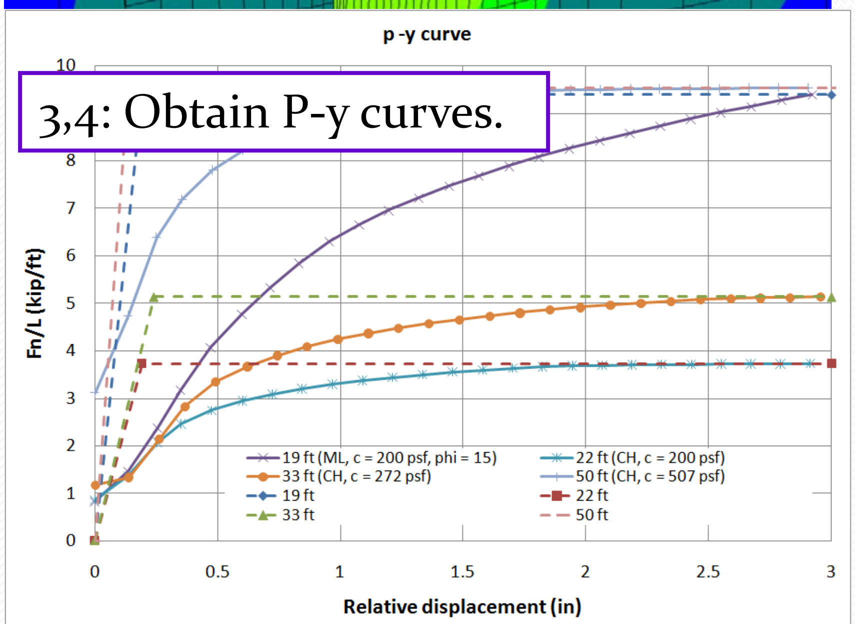
1,2: Perform pile loading tests with full 3-D analysis.



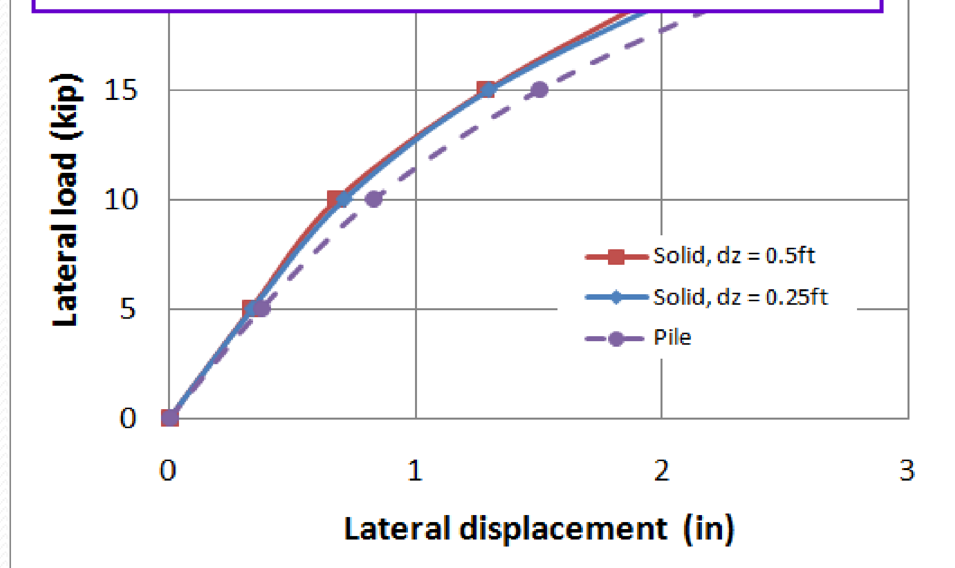
5: Perform pile loading tests with P-y curves and pile element.



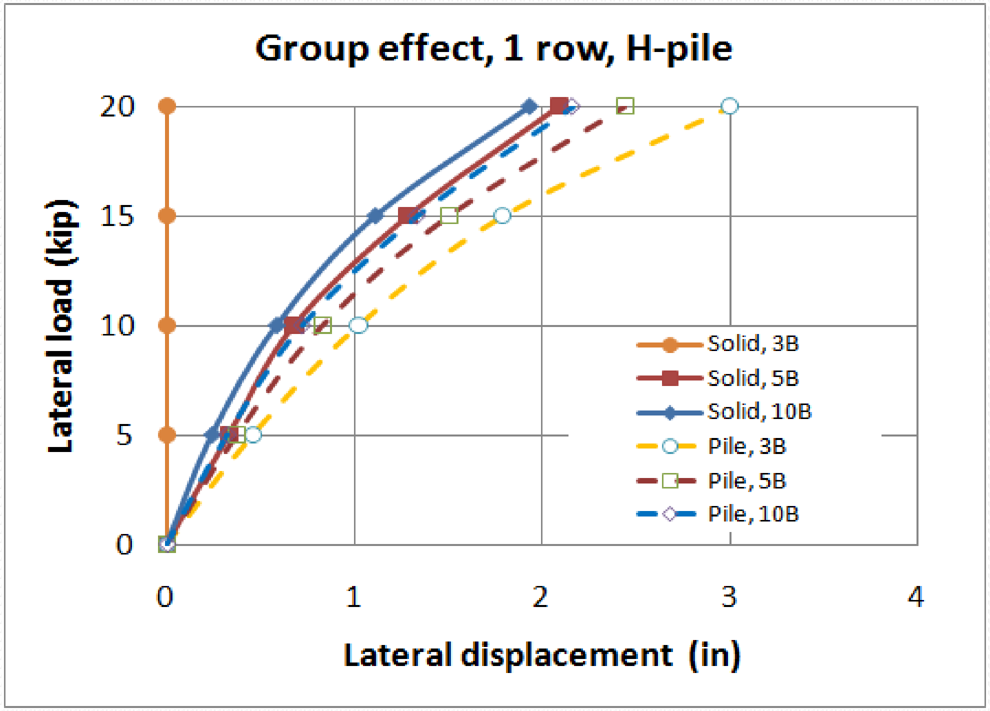
3,4: Obtain P-y curves.



6: Verify P-y curves by comparing full 3-D results and pile element results.

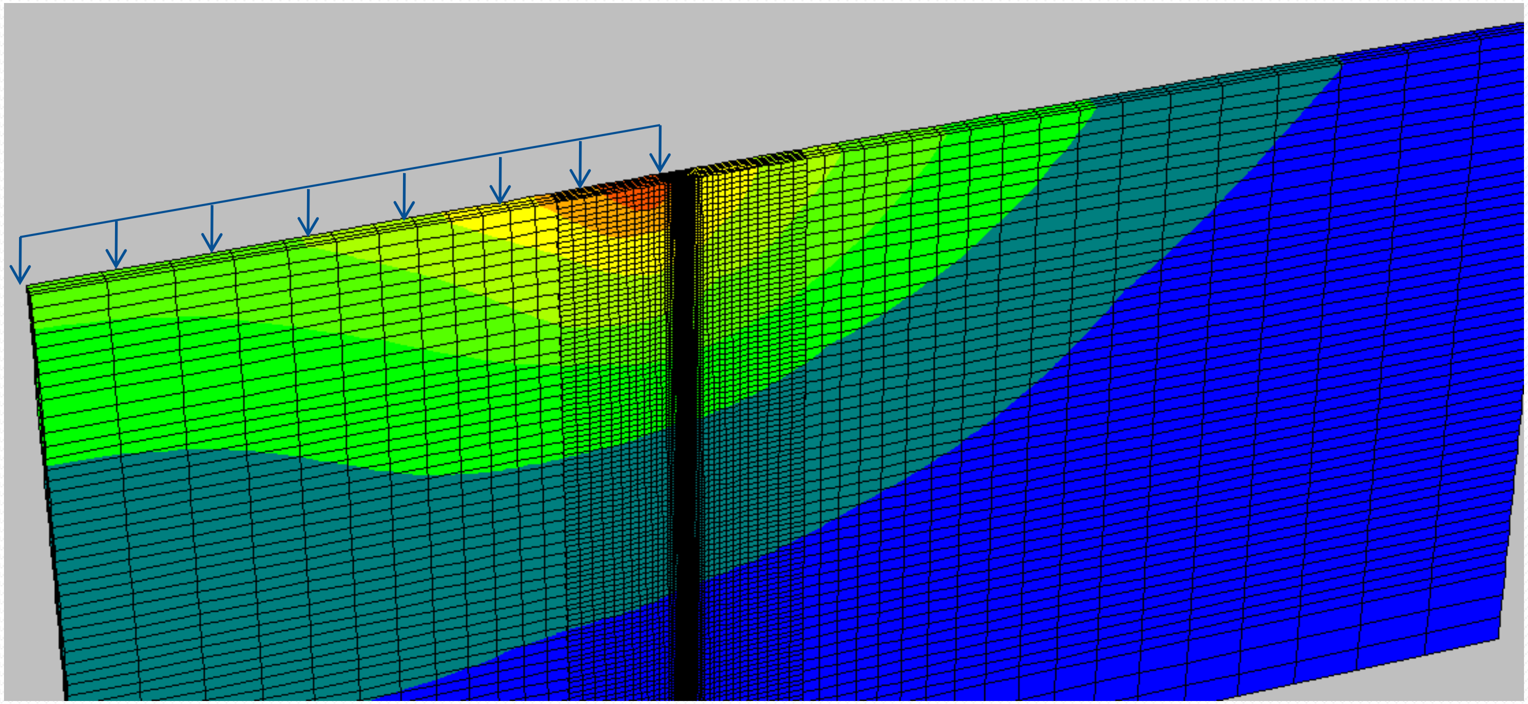


Group effect in active case

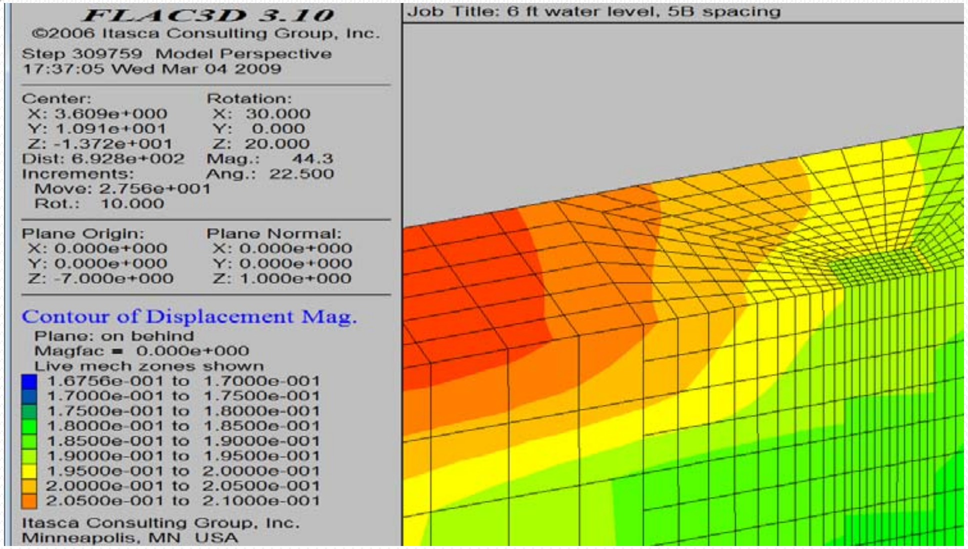


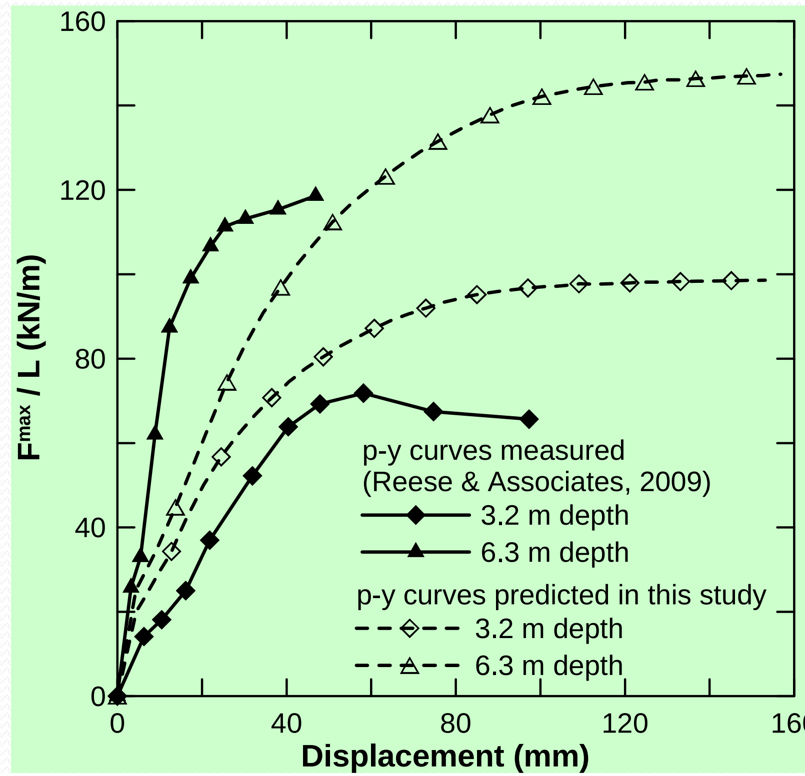
- Displacement increases in closely spaced pile.
- Group effect is automatically considered in pile 3D analysis.

3D analysis for passive case

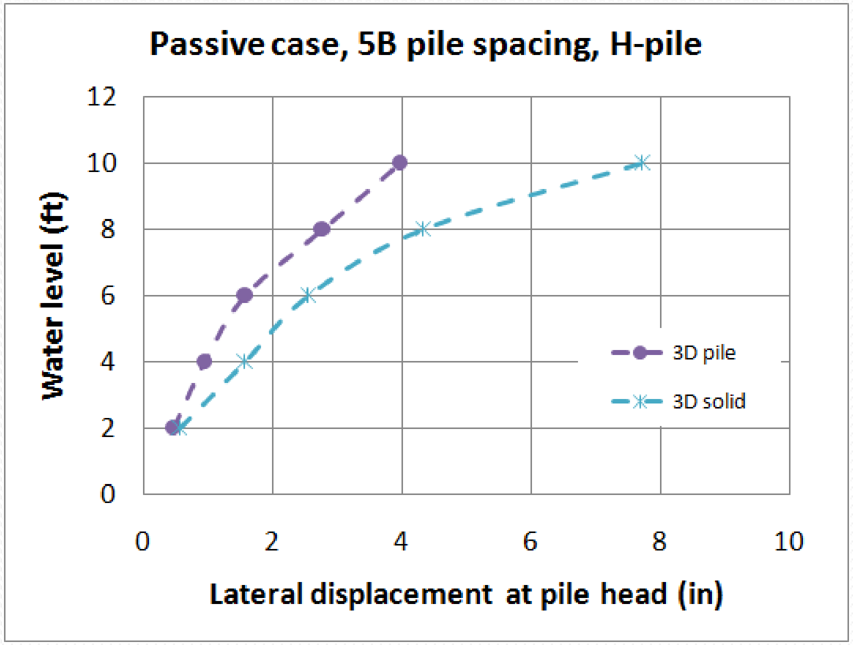


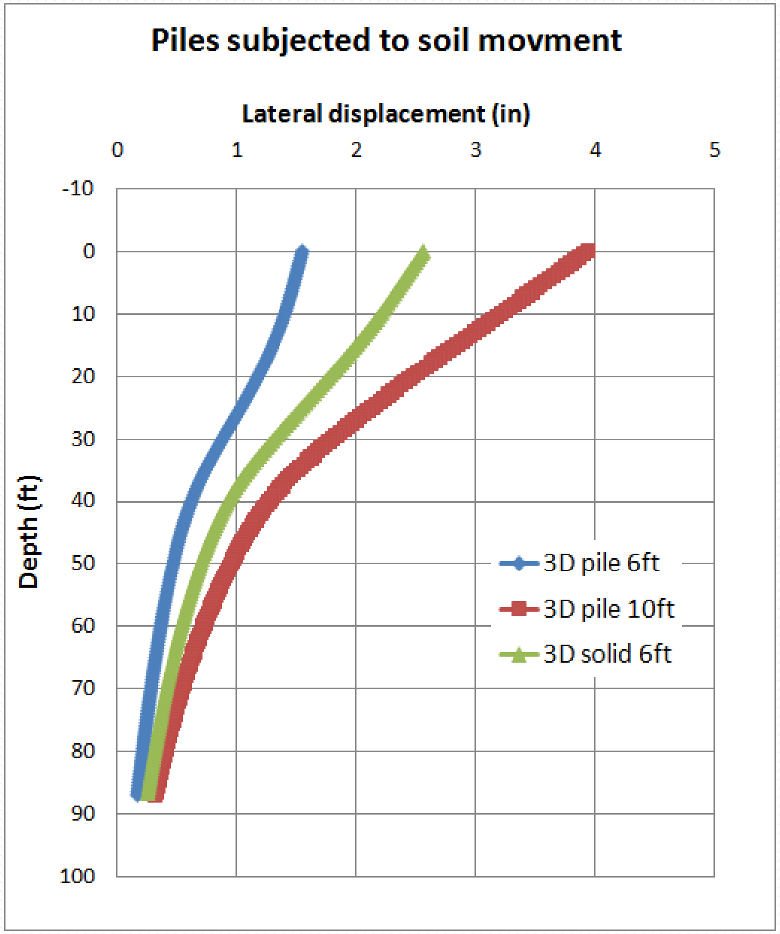
T-Wall Analysis
Calibration using lateral pile load test results





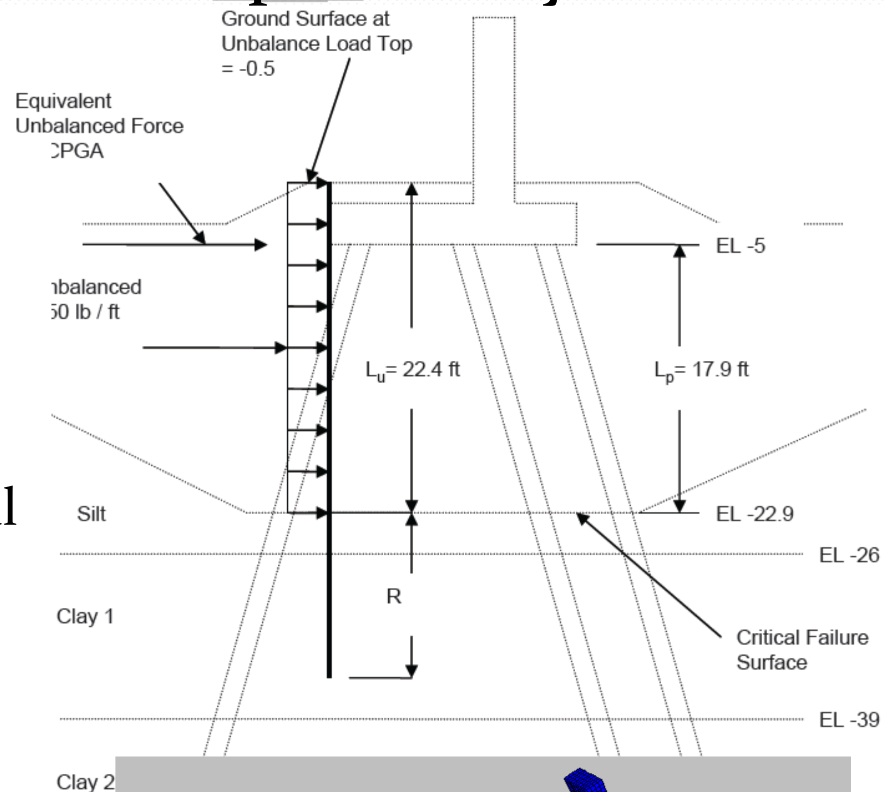
Pile top lateral displacement

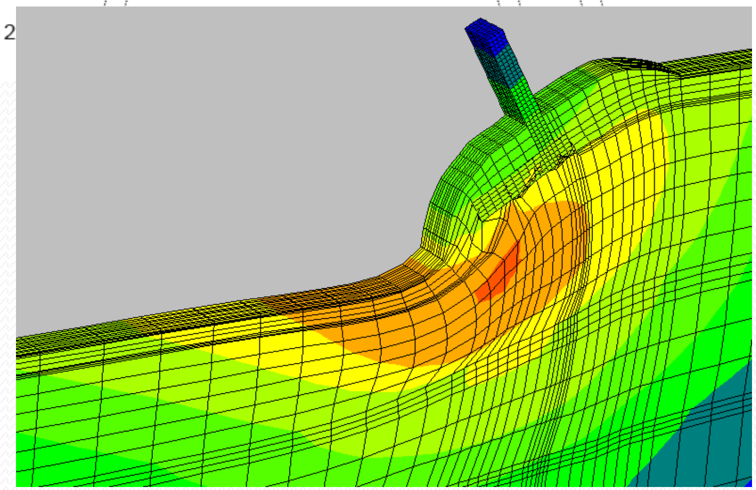




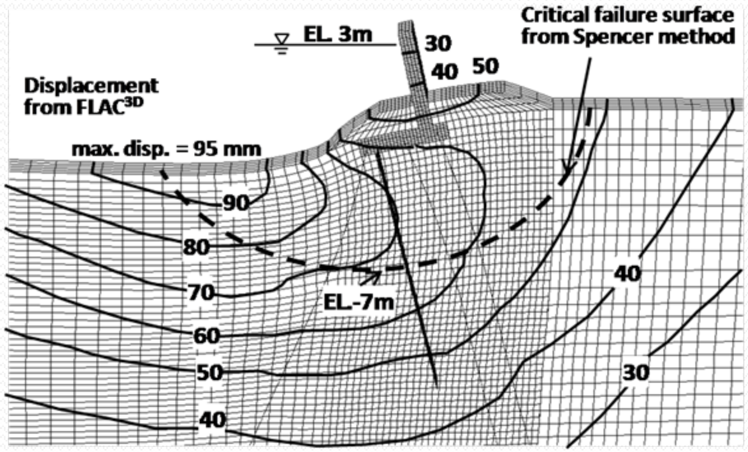
Task 2B: Soil-structure-fluid coupled analysis

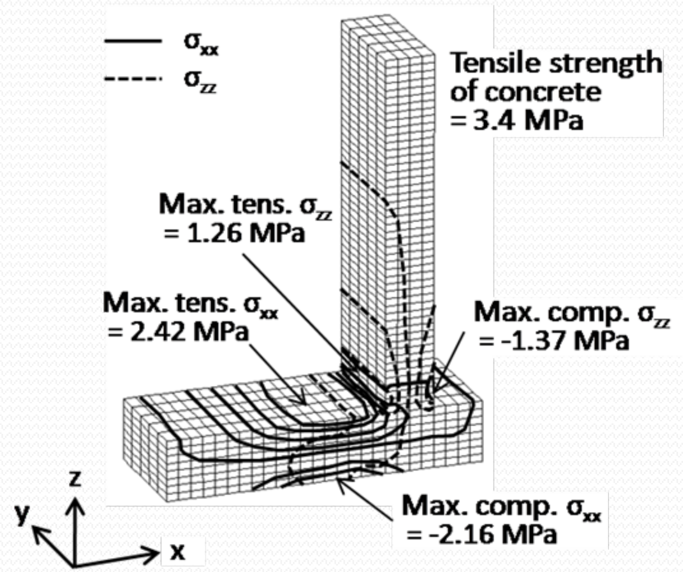
- Existing T-wall analysis is mostly 2-D analysis.
- 2-D analysis has limited capability in dealing with the frictional force that exist parallel to the mesh and normal stress and strains along the longitudinal direction.
- By using 3-D FLAC simulation with advanced constitutive models, realistic 3-D simulation of soil-structure interaction for T-wall is conducted.
- Similar 3-D simulation is also applied for floodwall and structure interfaces.

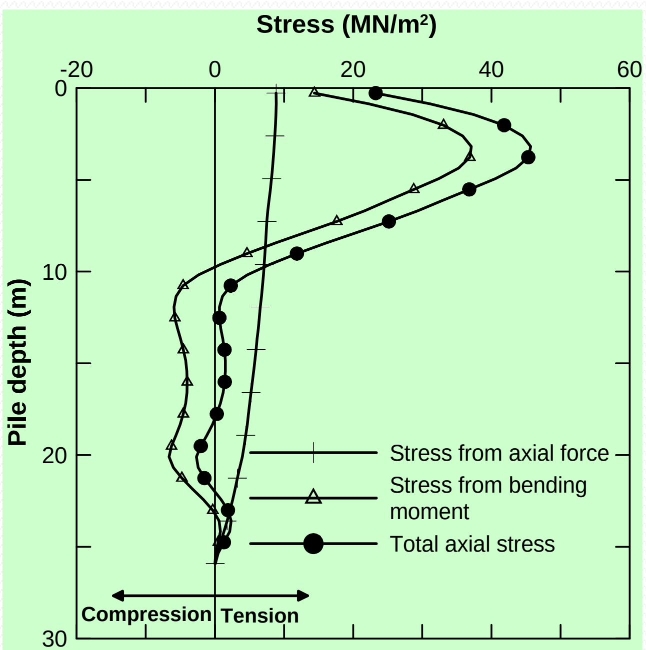


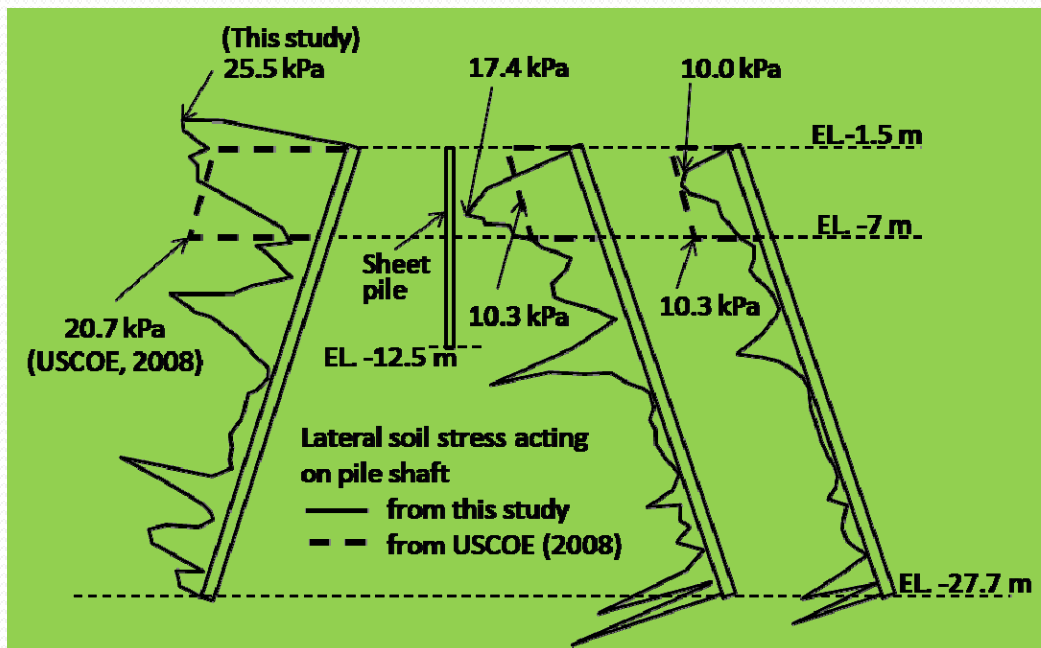


T-Wall Analysis
Behavior of Soils Around Piles









Summary

- Pile element provide very good results for active case, including group effect.
- Need validation for pile structural elements for passive case!

Acknowledgement

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Thank you