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STRUCTURAL RESPONSE TO PILE FOUNDATION STIFFNESS IN FEM STABILITY ANALYSIS

Master's thesis: The effect of modeling lateral stiffness of pile foundations on numerical analyses of structural frames

Aalto university, 2018

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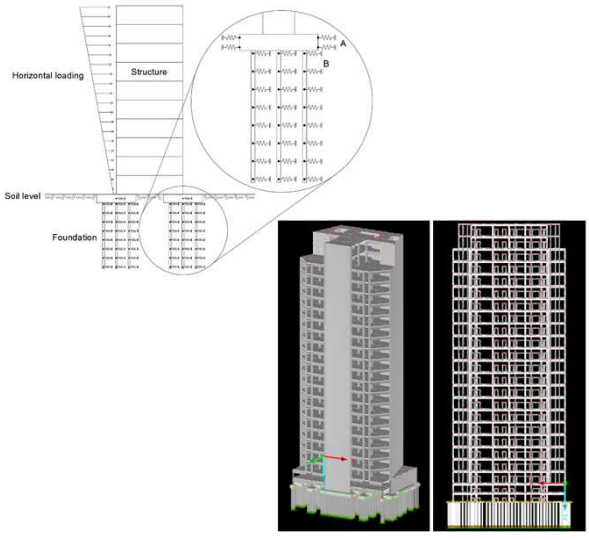
Goals of the thesis

- Analyze the structural sensitiveness to the variation on the pile foundation stiffness models in FEM stability analysis



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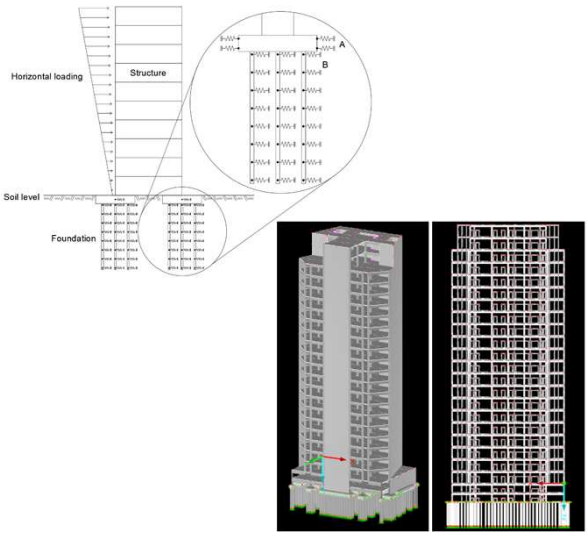
Goals of the thesis

- Analyze the structural sensitiveness to the variation on the pile foundation stiffness models in FEM stability analysis
- Reduce the usage of raking piles by relying on lateral resistance of piles



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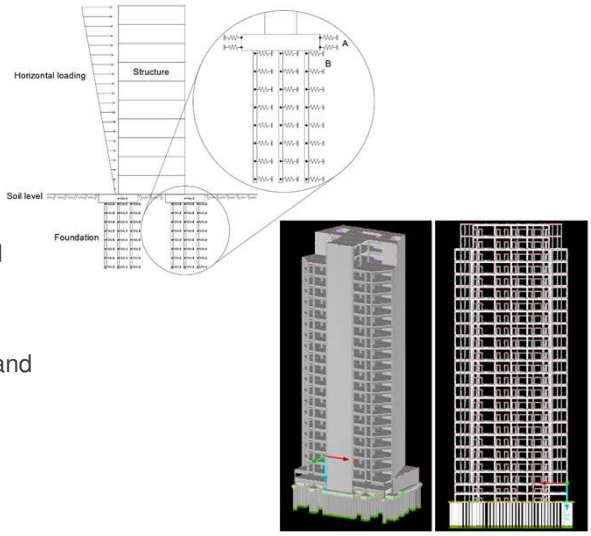
Goals of the thesis

- Analyze the structural sensitiveness to the variation on the pile foundation stiffness models in FEM stability analysis
- Reduce the usage of raking piles by relying on lateral resistance of piles
- Suggest an improved interaction between structural and geotechnical engineers



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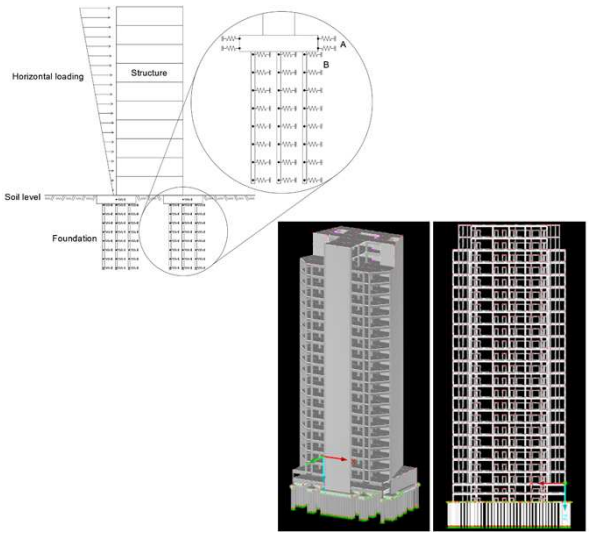
2018-10-17

Goals of this presentation

- Show how simplifications in pile foundation stiffness models affect structural stability analysis



3
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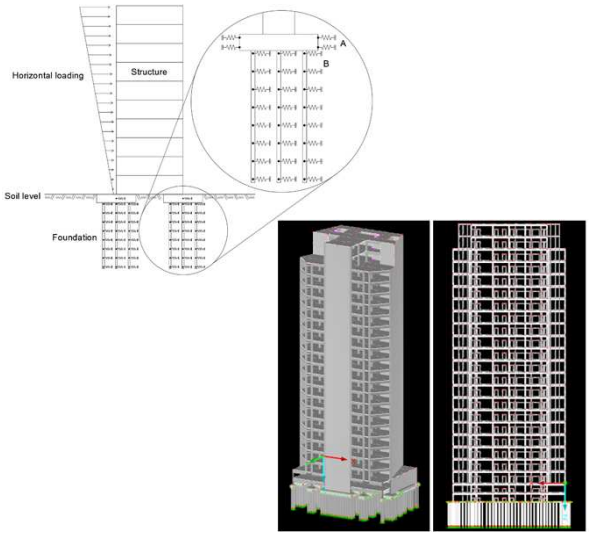
Goals of this presentation

- Show how simplifications in pile foundation stiffness models affect structural stability analysis
- What are the risks of simplifications in pile foundation stiffness



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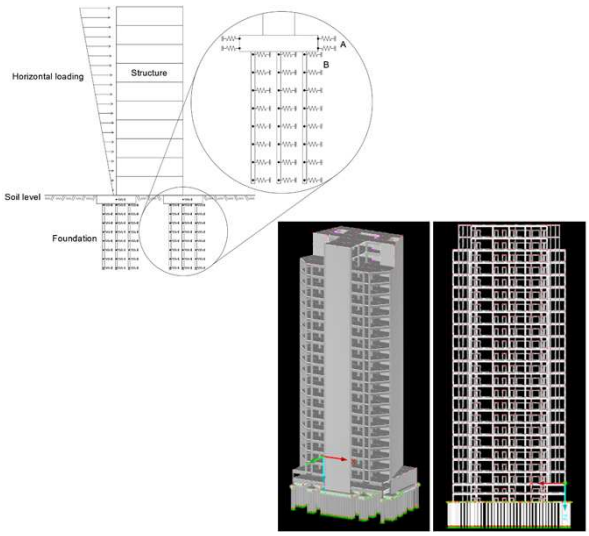
Goals of this presentation

- Show how simplifications in pile foundation stiffness models affect structural stability analysis
- What are the risks of simplifications in pile foundation stiffness
- How structural and geotechnical engineers can minimize the risks



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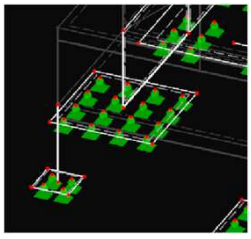
Models used in the analysis

	Model 01
Stiffness calculation	-
Group interaction	-
Spring distribution	-



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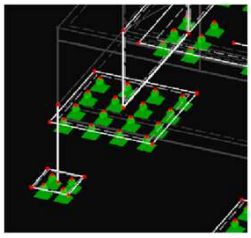
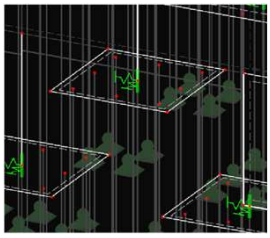
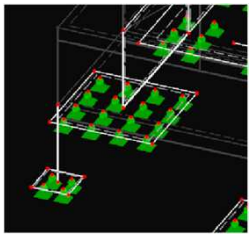
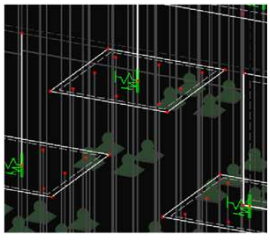
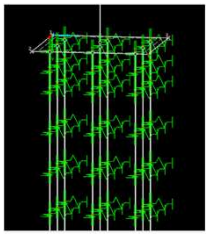
Models used in the analysis

	Model 01	Model 02
Stiffness calculation	-	Subgrade reaction approach
Group interaction	-	Front row resistance
Spring distribution	-	Middle of pile group

Models used in the analysis

	Model 01	Model 02	Model 03
Stiffness calculation	-	Subgrade reaction approach	P-y method with 100 cycles
Group interaction	-	Front row resistance	All piles
Spring distribution	-	Middle of pile group	Along the pile shaft

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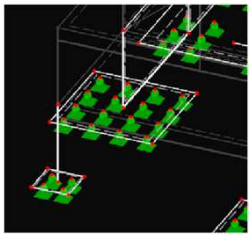
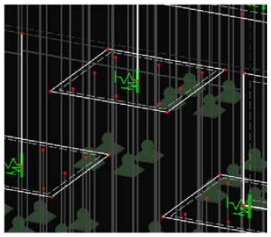
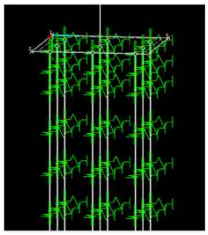
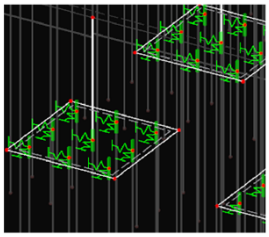
Models used in the analysis

	Model 01	Model 02	Model 03	Model 04
Stiffness calculation	-	Subgrade reaction approach	P-y method with 100 cycles	P-y method with 100 cycles
Group interaction	-	Front row resistance	All piles	All piles
Spring distribution	-	Middle of pile group	Along the pile shaft	On top of each pile head

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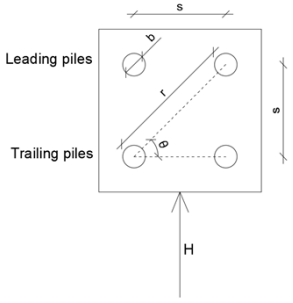
Pile group interaction



Group interaction for sand soils

				p-multiplier				
Author	Sand type	s/b *	Comment	Row 01	Row 02	Row 03	Row 04	Row 05
Brown et all (1988)	Medium dense over stiff clay	3	-	0.8 - 1.0	0.4	0.35	-	-
McVay et al (1998)	Loose and medium dense	3	-	0.8	0.4	0.3	0.2	0.3
Reese et al (2006)	No classification	3	*1	0.86	0.59	0.63	-	-
Al-Shamary et al (2018)	No classification	3		0.58	0.46	0.39	-	-

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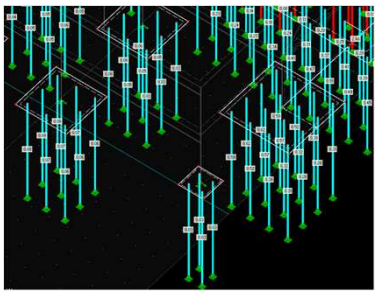
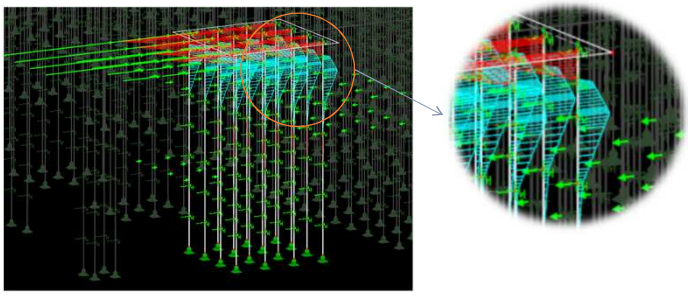
Results obtained - internal forces of piles

Results	Model 01	Model 02	Model 03	Model 04
Internal forces (N, V, M)	No pile results	N	N, V, M	N, V

Bending moment Model 02 and 04



Bending moment Model 03



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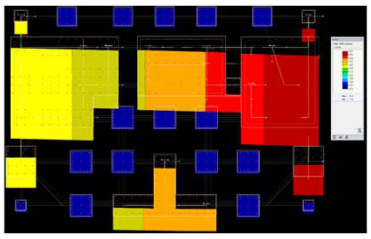
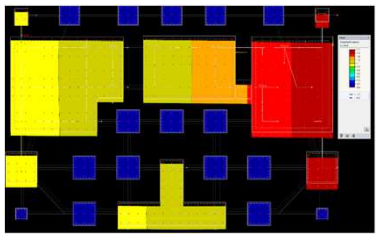
Results obtained – foundation deformation

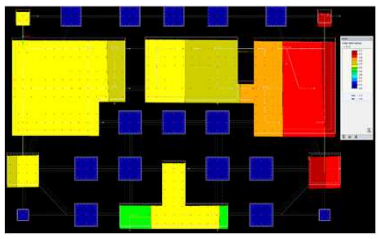
Results	Model 01	Model 02	Model 03	Model 04
Internal forces (N, V, M)	No pile results	N	N, V, M	N, V
Foundation deformation	None	Up to 6,3 mm	Up to 1,7 mm	Up to 1,2 mm



Model 02 (scale 0…6,3mm)

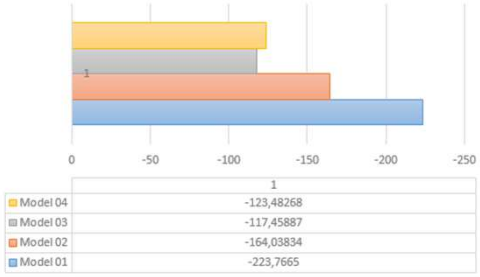


Model 03 (scale 0…1,7mm)

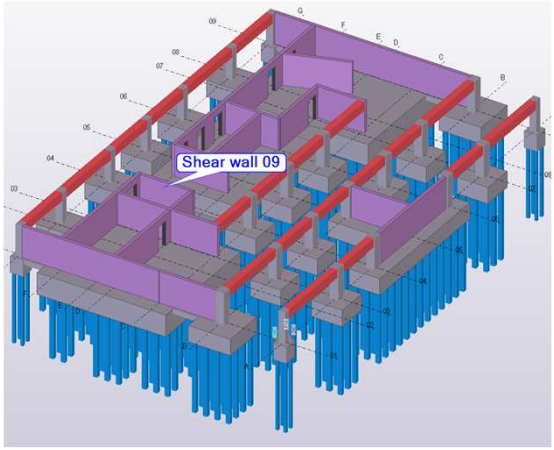


Model 04 (scale 0…1,2mm)

Results obtained – load transfer on bearing structure



Resultant of shear force in wall 09



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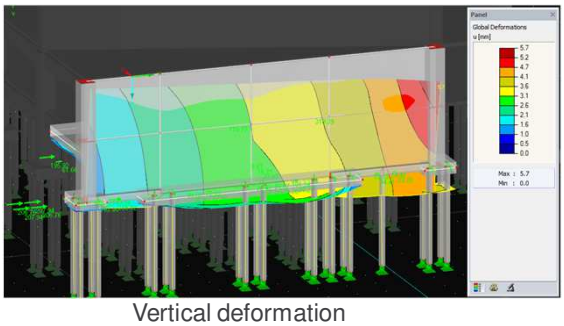
Results obtained – deformation and forces

- Lateral loading from structural deformation



Vertical deformation

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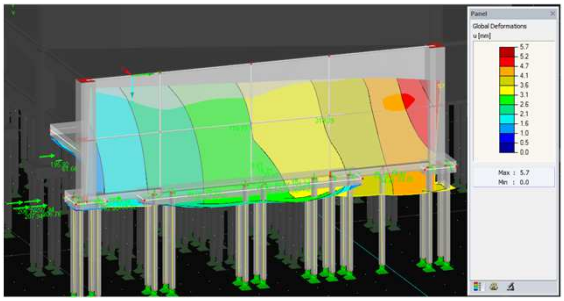
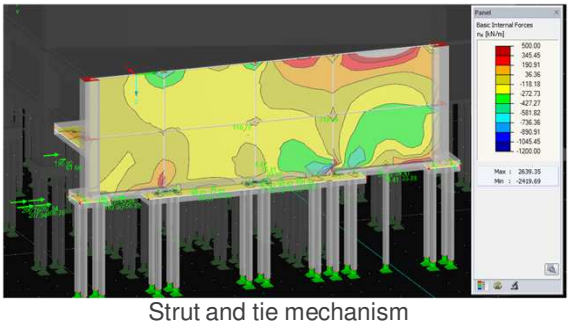
Results obtained – deformation and forces

- Lateral loading from structural deformation

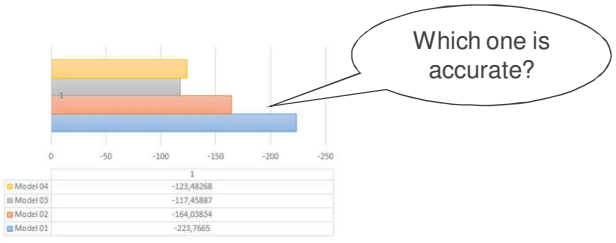


Vertical deformation



Strut and tie mechanism

Time for reflection



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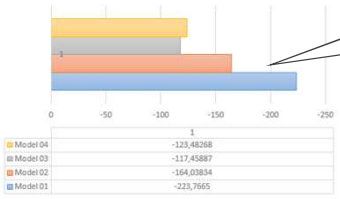
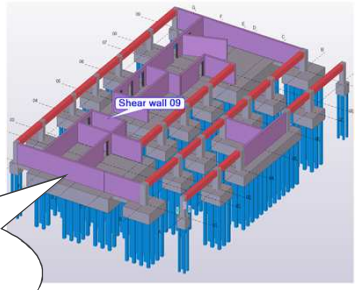
Time for reflection



Which one is accurate?

How accurate will be the load transfer in the stiffening elements?



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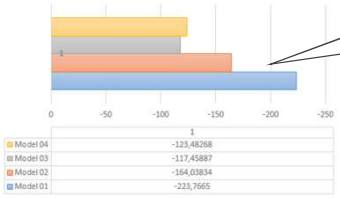

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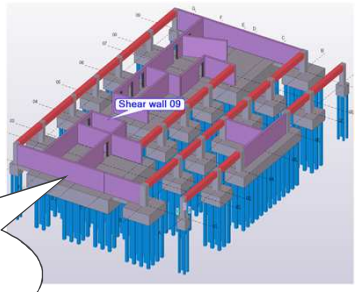
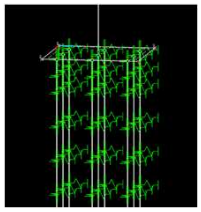


Answer: depends on how accurate is your foundation model



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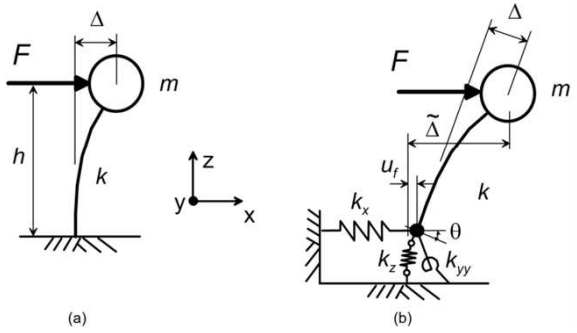
Soil-Structural interaction (SSI)

- General overview



Steward, J.P et. al. (2012)

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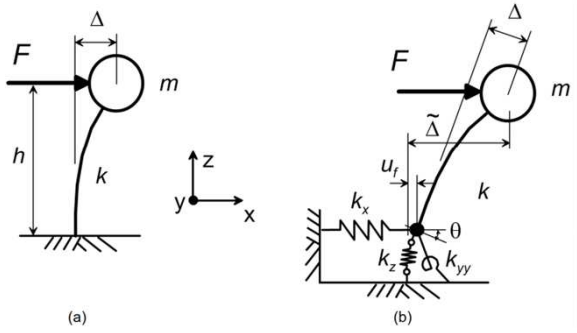
Soil-Structural interaction (SSI)

- General overview
- Soil response under different loads
  - Dynamic
  - Sustained
  - Short-term static
  - Cyclic



Steward, J.P et. al. (2012)

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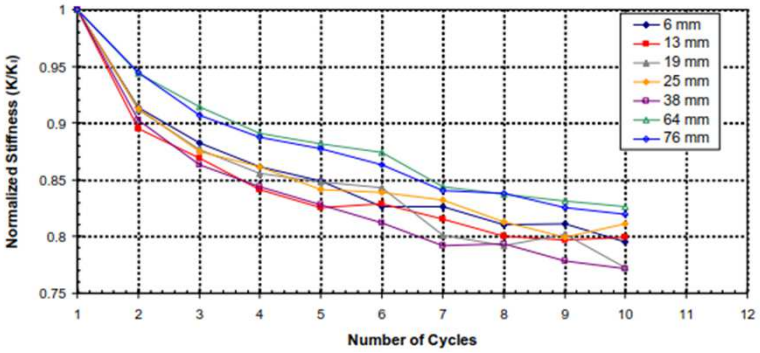
Soil-Structural interaction (SSI)

- Cyclic response



Walsh, J. M. (2005)

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Soil-Structural interaction (SSI)

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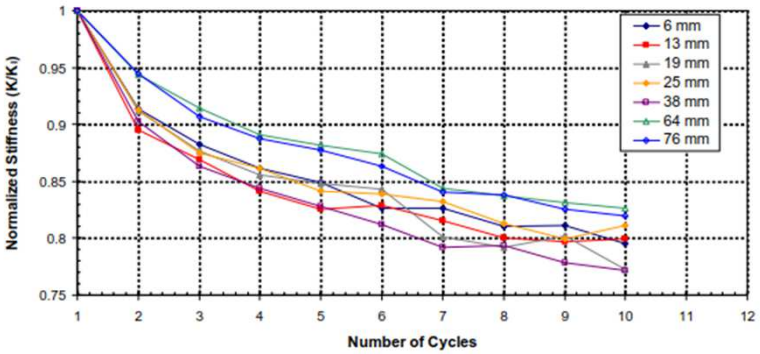

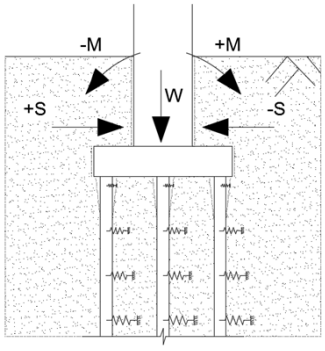

Walsh, J. M. (2005)

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Pile utilization factor

- Should it be calculated all piles in Ultimate Limit State?

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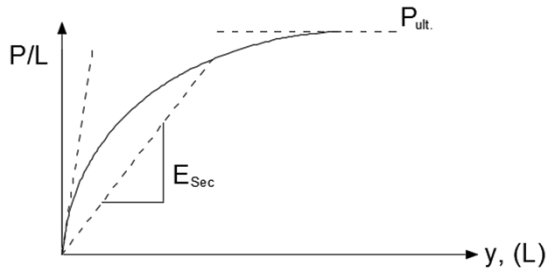
  - **Maybe not!** Pile stiffness is dependent on the load it was calculated to carry.



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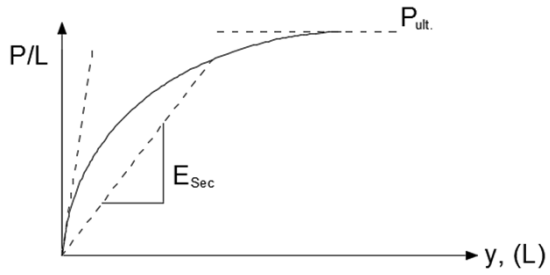
Pile utilization factor

- Should it be calculated all piles in Ultimate Limit State?
  - **Maybe not!** Pile stiffness is dependent on the load it was calculated to carry.
  - Optimal to use loads closer to what it is actually carrying in the FEM calculations



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How to reduce risks and make a more accurate design?

Increase communication between Structural and geotechnical engineering

- Exchange needed and relevant data before design
  - What is needed in the other field to make accurate calculations?

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How to reduce risks and make a more accurate design?

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- Exchange recommendations and information about structure and soil.
  - Loadings, deflections, special limitations, type of analysis and others.

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Advantages

- Avoid overusing raking piles

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Advantages

- Avoid overusing raking piles
- Avoid under or over design and increase reliability of design

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- Regular meetings and verifications in later design stages to verify results

Advantages

- Avoid overusing raking piles
- Avoid under or over design and increase reliability of design
- Create a more economical foundation solutions for the customer

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Some reference and contact information

- **Master's thesis (Aalto University): The effect of modeling lateral stiffness of pile foundations on numerical analyses of structural frames (Publication date: 01.11.2018)**

  – Reese, L. C.˙, Isenhower, W. M., Wang, S. T.. K.(2006) Analysis and design of shallow and deep foundations. USA: Jhon Wiley e sons. 574 p. ISBN978-0-471-43159-6.

  – Stewart, J. P., Crouse, C. B., Hutchinson, T., Lizundia, B., Naeim, F., Os-tadan, F. (2012) Soil-Structure Interaction for Building Structures. Available from: https://www.nist.gov/publications/soil-structure-interaction-building-structures [Accessed on 13 June 2018]

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