

SYMPOSIUM : NUMERICS IN GEOTECHNICS & STRUCTURES



26 YEARS ZSOIL.PC

DATE

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**Better ZSOIL,
Better Geotechnical Analysis**

**—Practice of Pile Foundation Treatment
Based on ZSOIL.PC**

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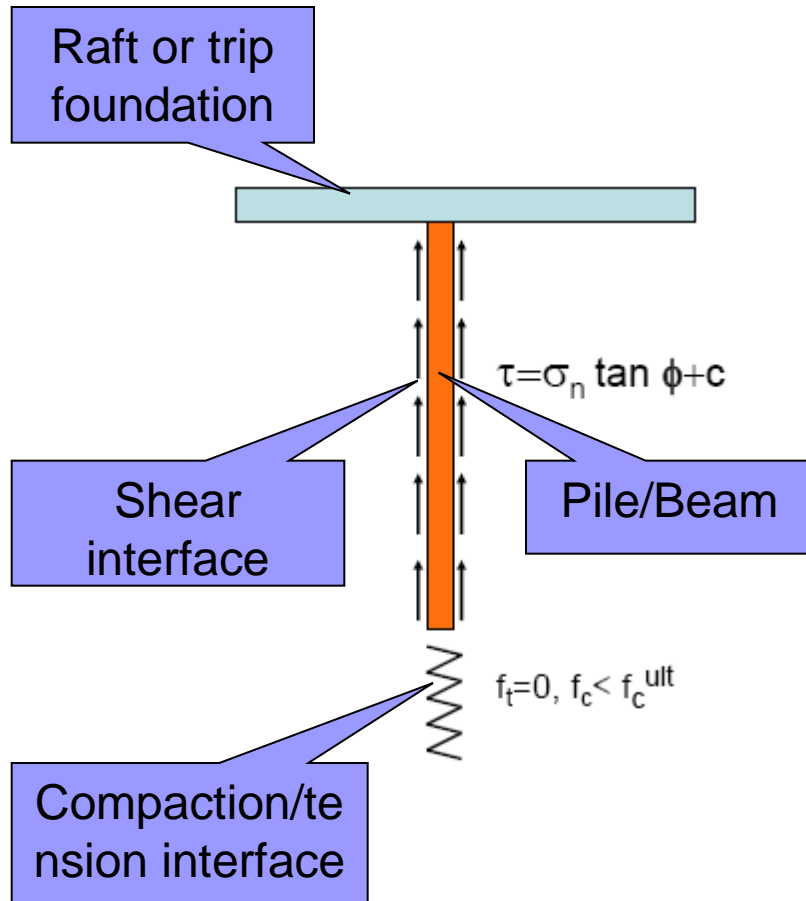
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- Functions related to Pile Foundation Design of ZSOIL.PC
 - Pile element
 - Borehole
 - Nodal link

Functions related to Pile Foundation of ZSOIL.PC

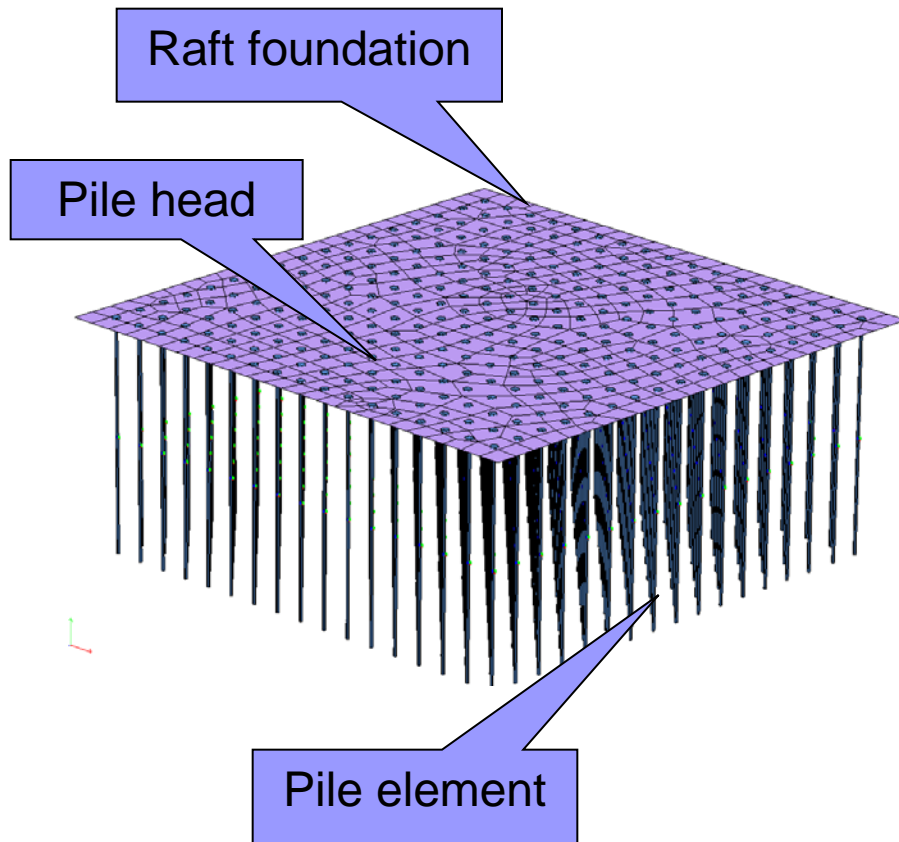
Pile element



- Mechanical Features of Pile element
 - Pile element contains pile (structure element), lateral skin shear interface and toe compaction/tension interface
 - The interaction between pile and surrounding soil can be modeled with skin and toe interface, which comply with Mohr-Coulomb strength criterion
 - Pile (structure element) inherits all the properties of beam element

Functions related to Pile Foundation of ZSOIL.PC

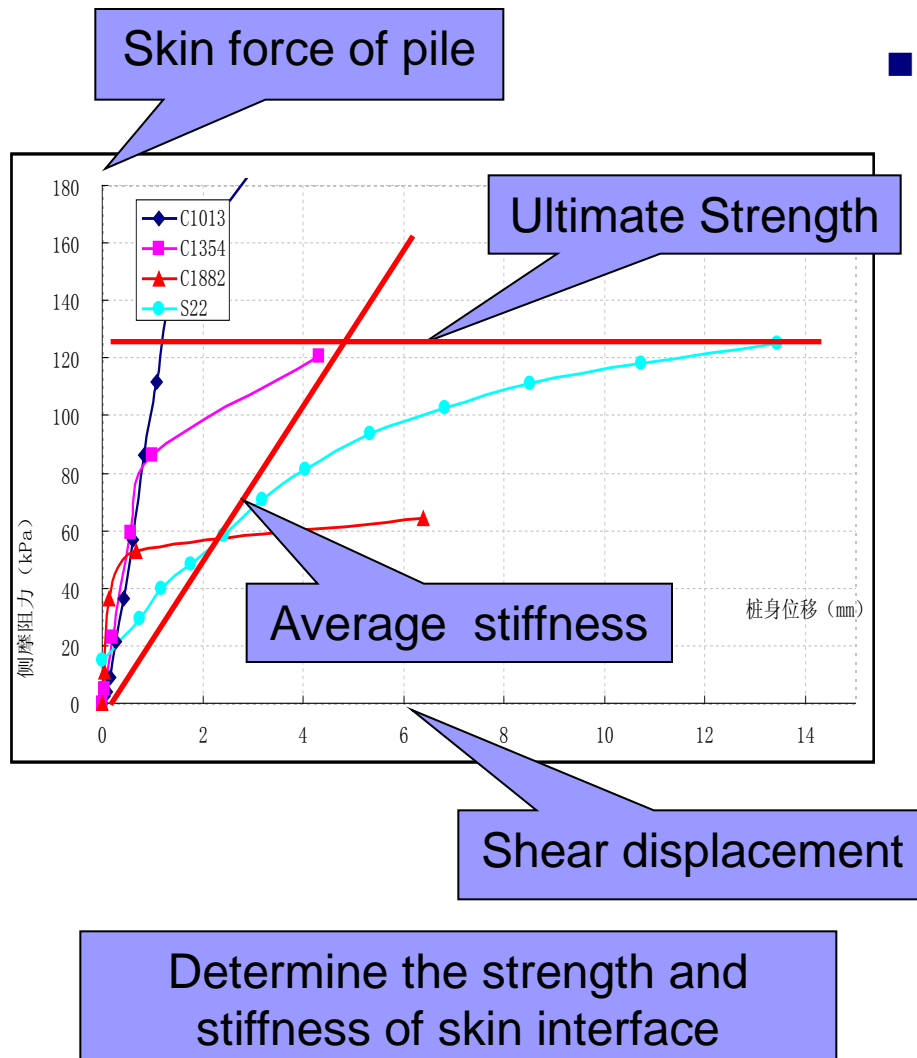
Pile element



- Modeling of Pile element
 - Hundreds of pile elements can be generated “on objects” within several seconds, which usually imported from DXF files
 - Pile head can be automatically “link to” raft or trip foundation smartly, which can save us many hours to “merge” pile head and nodes of solid element
 - Axial force, moment and shear force can transfer from piles to raft , and vice versa
 - The length of each segment of pile should be compatible with the length of the soil element, not too large nor too small
 - If layout of piles change, import the modified DXF file again

Functions related to Pile Foundation of ZSOIL.PC

Pile element



Parameters of pile element

- Parameters of pile (structure) is easy to determine when the style of pile is selected
- Parameters of skin and toe interface can inherit from surrounding soil. Default settings of the program can cope with most of the situation, however, accuracy is not too high
- **In-site test, like pile static load test with strain gauge set in different depth of pile, is necessary for “fine” analysis of pile foundation.** We can gain strength and stiffness of skin interface though diagraph of shear displacement vs. skin force
- To comply with design code, zero friction angle of pile skin interface is necessary

Functions related to Pile Foundation of ZSOIL.PC

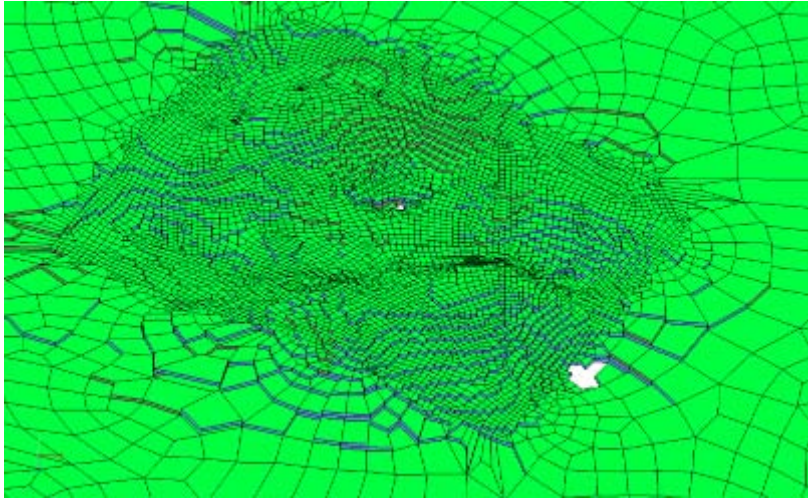
Borehole



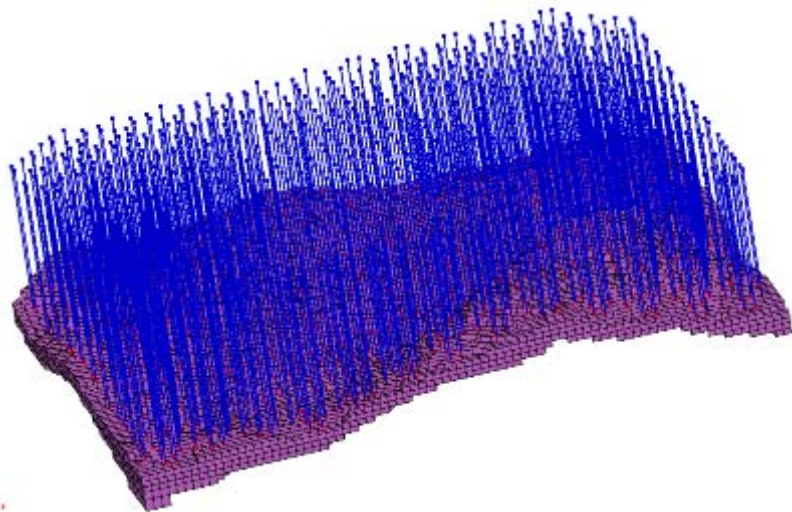
- Complex spatial distribution of soil
 - “Borehole” function helps to generate complex spatial distribution of soil material easily without 3D surface generated.
 - It is convenient to add boreholes any time to **update** spatial distribution, which can save us many hours **too**

Functions related to Pile Foundation of ZSOIL.PC

Borehole + Pile element

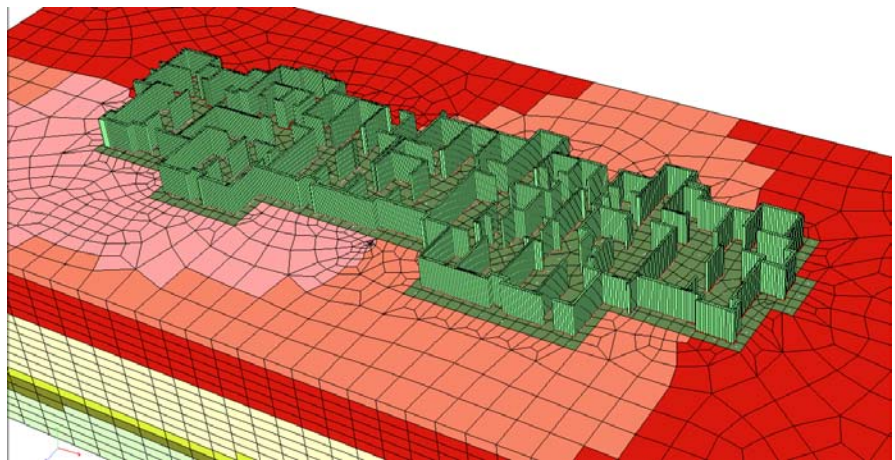
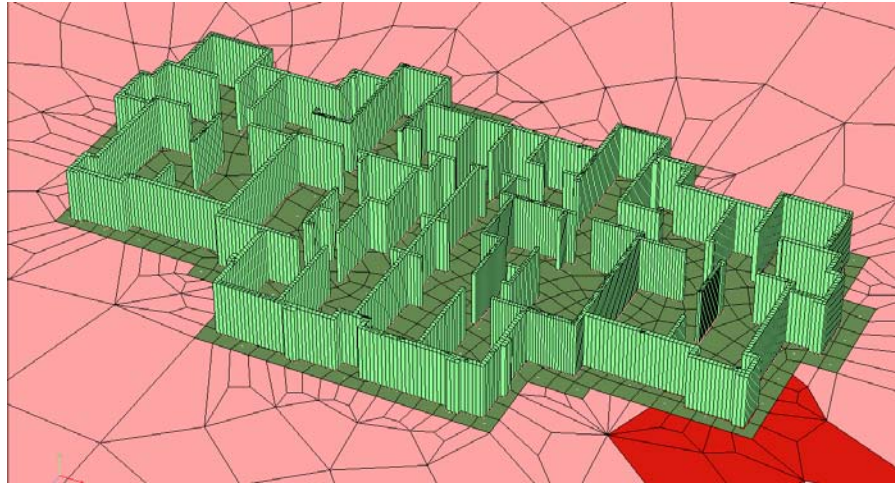


- All for the sake of Engineers
 - Step 1: hide all the soil above the bearing layer of pile
 - Step 2: “select visible faces”, then all the face of bearing layer is selected
 - Step 3: “Macro model\Point\Project\On selected faces in direction”, then all the pile toes stand on the bearing layer
 - Step 4: move the pile toes some distance into the bearing layer if necessary
 - It is very convenient to “stick” hundreds of piles on the bearing layer



Functions related to Pile Foundation of ZSOIL.PC

Nodal link



- Set the mind free
 - Super structure can be connected to the foundation by nodal link, **without compatible mesh**
 - Very fine structure model can be avoided, which will significantly increase the number of the elements of the whole model
 - Structure model can be established in another file .It can be assembled with soil and foundation when necessary.



■ Practice of Pile Foundation Treatment

- General information
- Challenge
- Pile static load test
- 3D FEM analysis

Practice of Pile Foundation treatment

General information



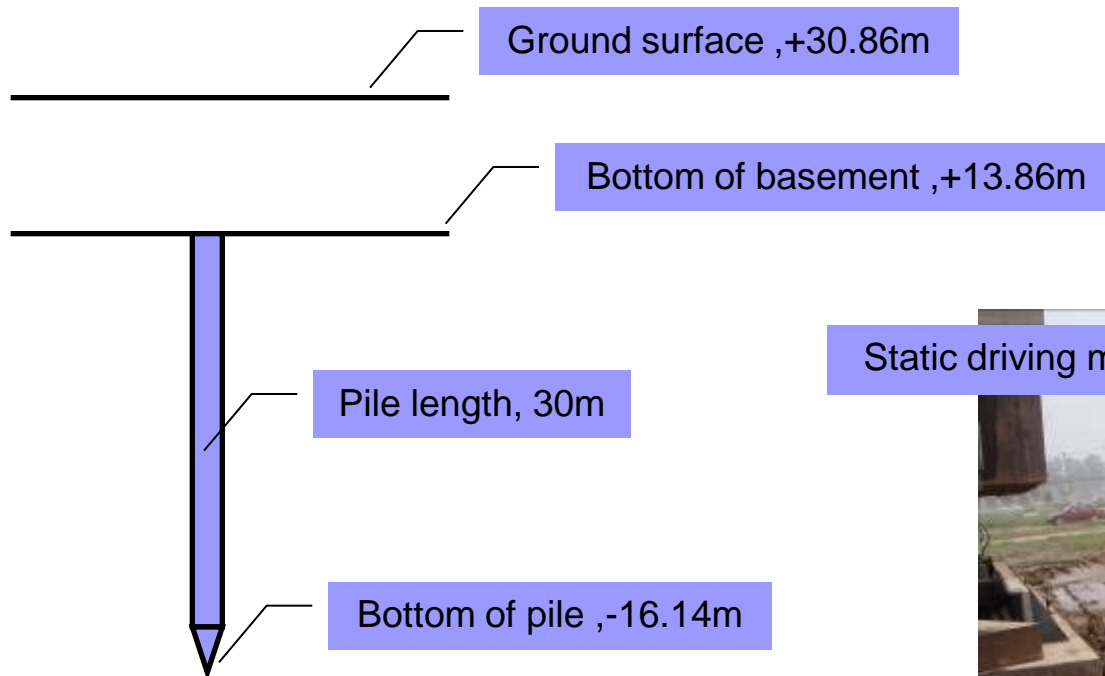
- Information of super structure
 - Frame shear wall structure, 26F(105m), basement 2F(16.5m depth)

Practice of Pile Foundation treatment

General information

Information of pile

- Pre-stressed concrete pipe pile (PHC), diameter 500mm, thickness 125mm, length 30.0m (segment I : 15m + segment II : 15m), bearing capacity 2500kN
- Static piling method is used to drive the pile

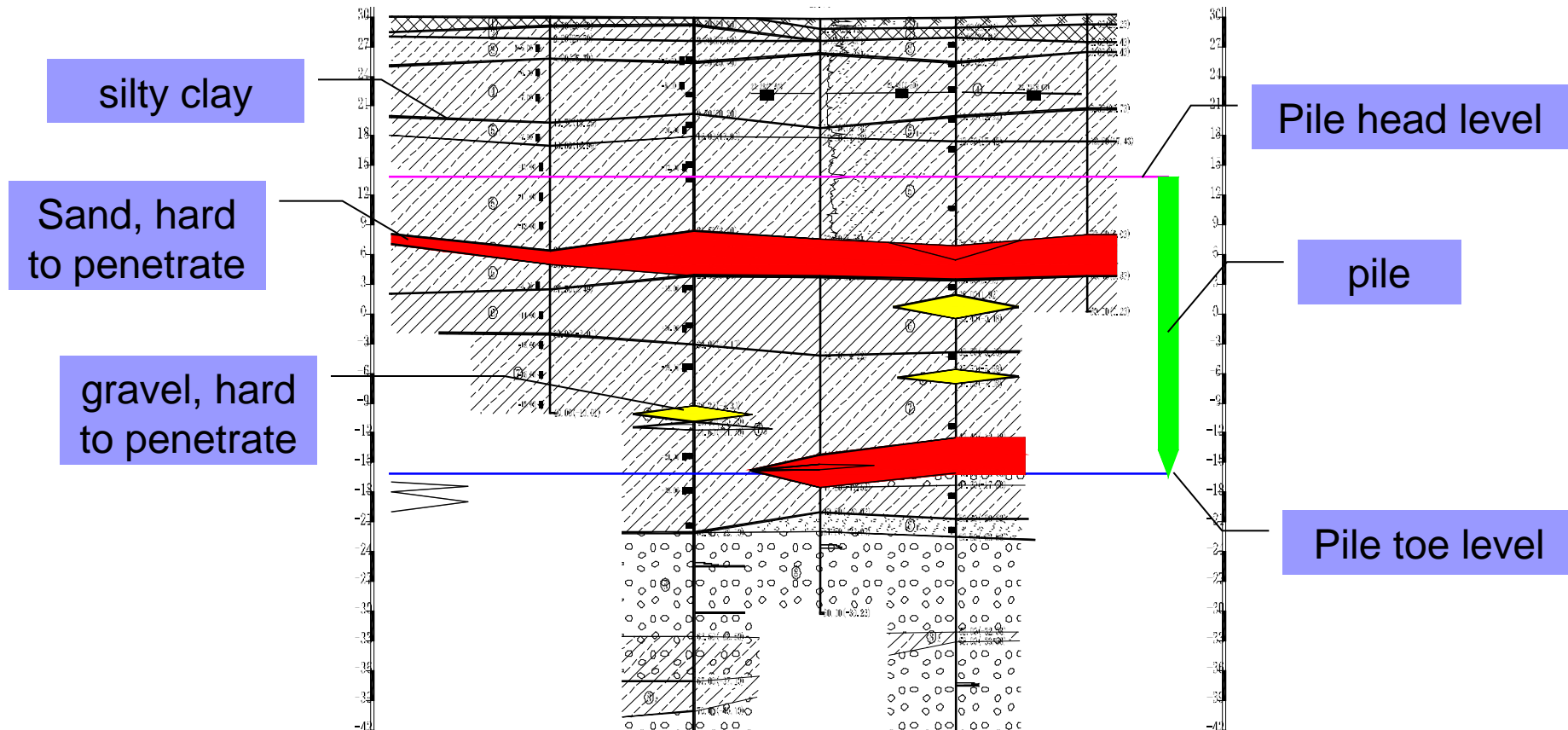


Practice of Pile Foundation treatment

General information

Information of geology conditions

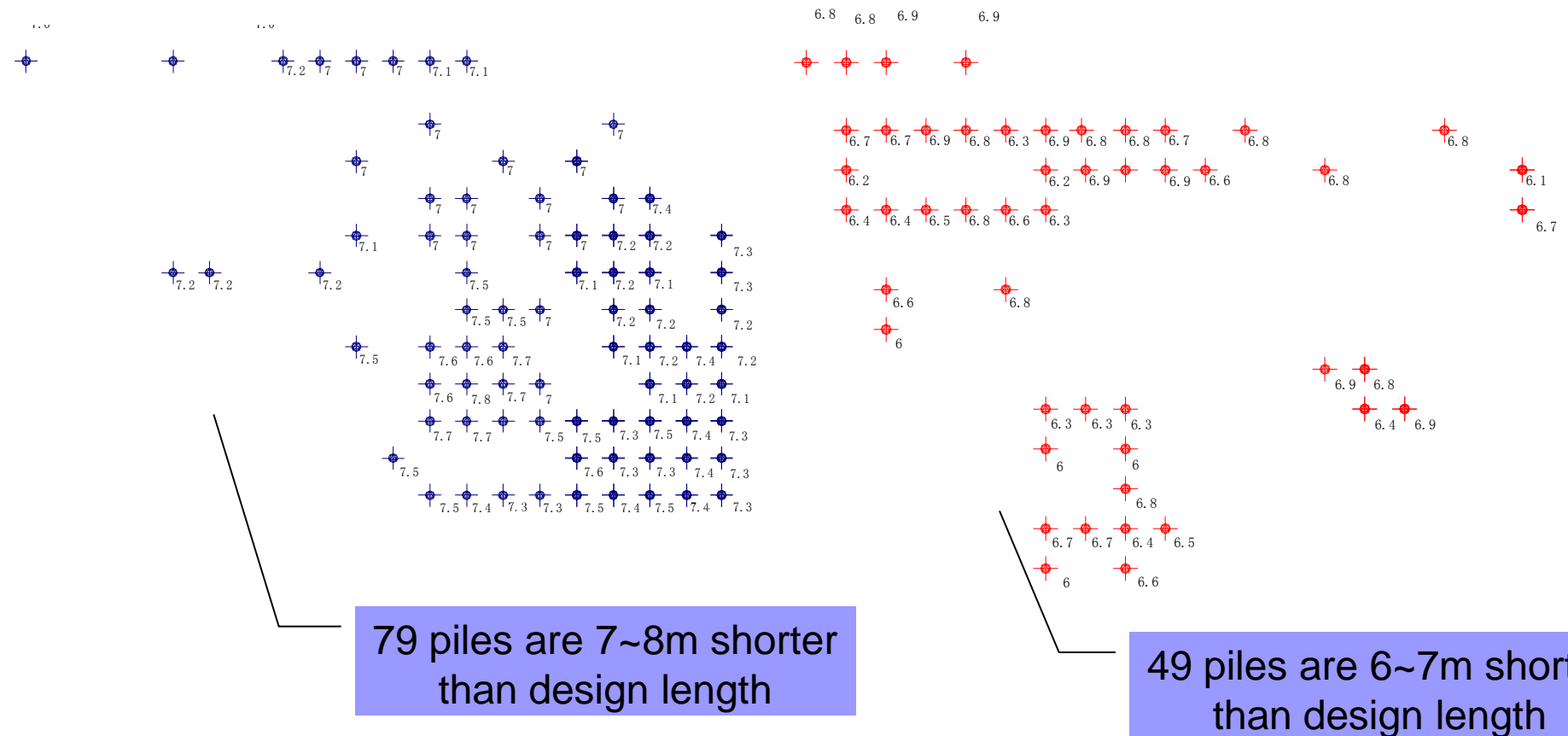
- The site is mainly composed of silty clay ($N/SPT=10\sim12$, $P_s/CPT=1.5\sim2.5\text{Mpa}$) and middle sand ($N/SPT=22\sim30$, $P_s/CPT=10.0\sim15.0\text{Mpa}$)



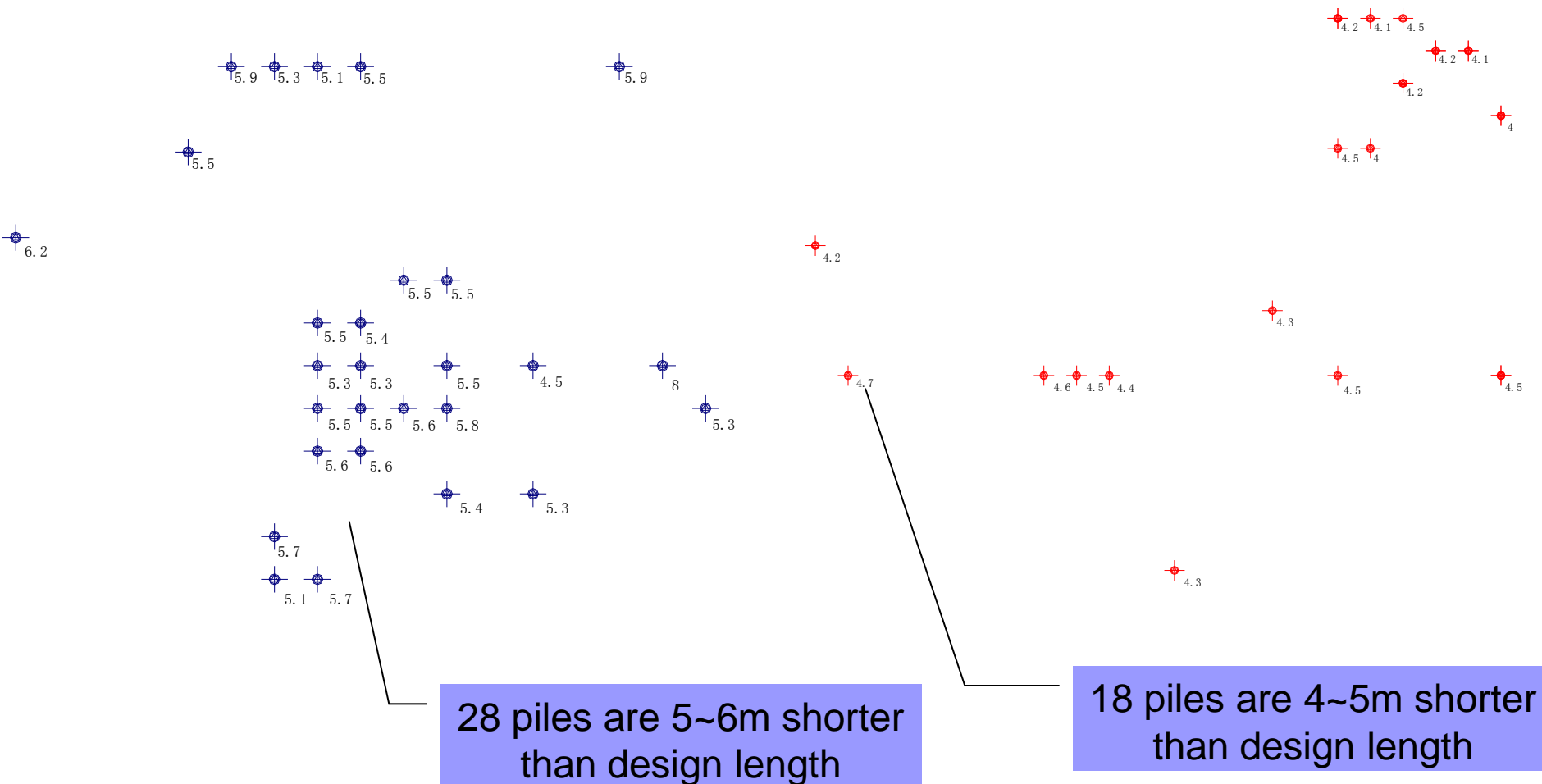
Practice of Pile Foundation treatment

Challenge

- According to the construction records, 200+ piles are shorter than design length (30m)
- Irregularly distributed “hard layer” may be the reason

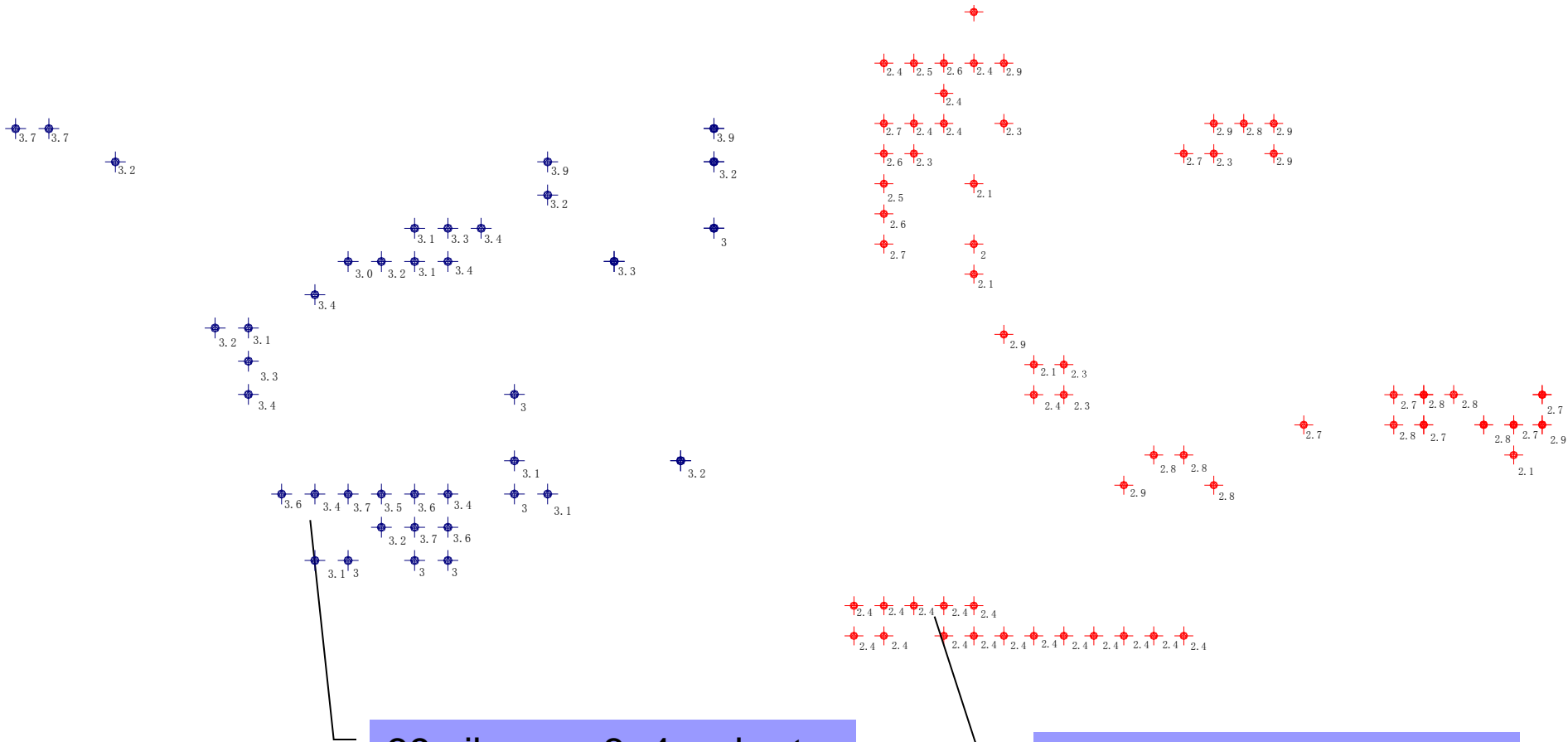


Practice of Pile Foundation treatment Challenge



Practice of Pile Foundation treatment

Challenge



Practice of Pile Foundation treatment

Challenge

- It seems impossible to drive additional piles into the ground to compensate the lack of bearing capacity.
 - There is no room left, even for only 1 pile.
- It seems impossible to move to another site to construct the building.
 - Kidding?
- Maybe our client has to reduce the height of the building.
 - maybe
- With so many “short” piles, is the foundation safe enough to support the load of the building?

Practice of Pile Foundation treatment

Challenge

- How to help our client?
 - We need to know the exact load applied to each pile.
 - Super structure-foundation-soil interaction theory can be employed to calculate the load of each pile.
 - Pile static load test can be used to determine the real bearing capacity of piles with different length, especially the shortest piles.
 - We can judge the safety factor of each pile.
 - We can calculate the settlement of the building.

Practice of Pile Foundation treatment

Pile static load test

We select 7.0~8.0m shorter piles to implement pile static load test. If the bearing capacity of the shortest piles is OK, of course ,the capacity of other piles will be OK.

Pile static load test



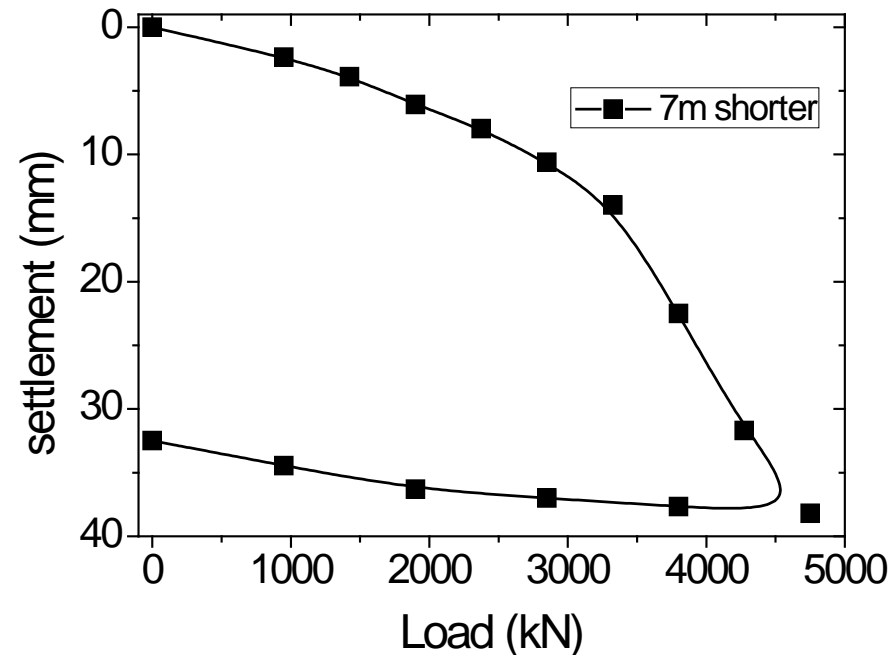
Steel beam

Hydraulic jacks



Practice of Pile Foundation treatment

Pile static load test



- Three 7.0m shorter piles are selected to test.
 - We select the shortest piles to represent the whole piles.
- According to the diagraph of load vs. settlement, the max. load of the test is about 4750kN.
- The current bearing capacity of the tested pile is $4750/2=2375$ kN.
 - The design bearing capacity is 2500kN.
 - The current bearing capacity is about 5% smaller than the design value.
- Is the current bearing capacity enough ?
 - What the 3d FEM analysis tell us?

Practice of Pile Foundation treatment

3D FEM analysis

- Some details should be considered in the analysis
 - The effective length of the piles ,bearing layer and the depth into the bearing capacity are very different.
 - The distribution of stiffness of the super structure will affect the settlement value.
 - The distribution of stiffness of the super structure will affect distribution of the settlement of the foundation.
 - The thickness of the raft will play the positive role of the settlement compatibility between raft and piles.

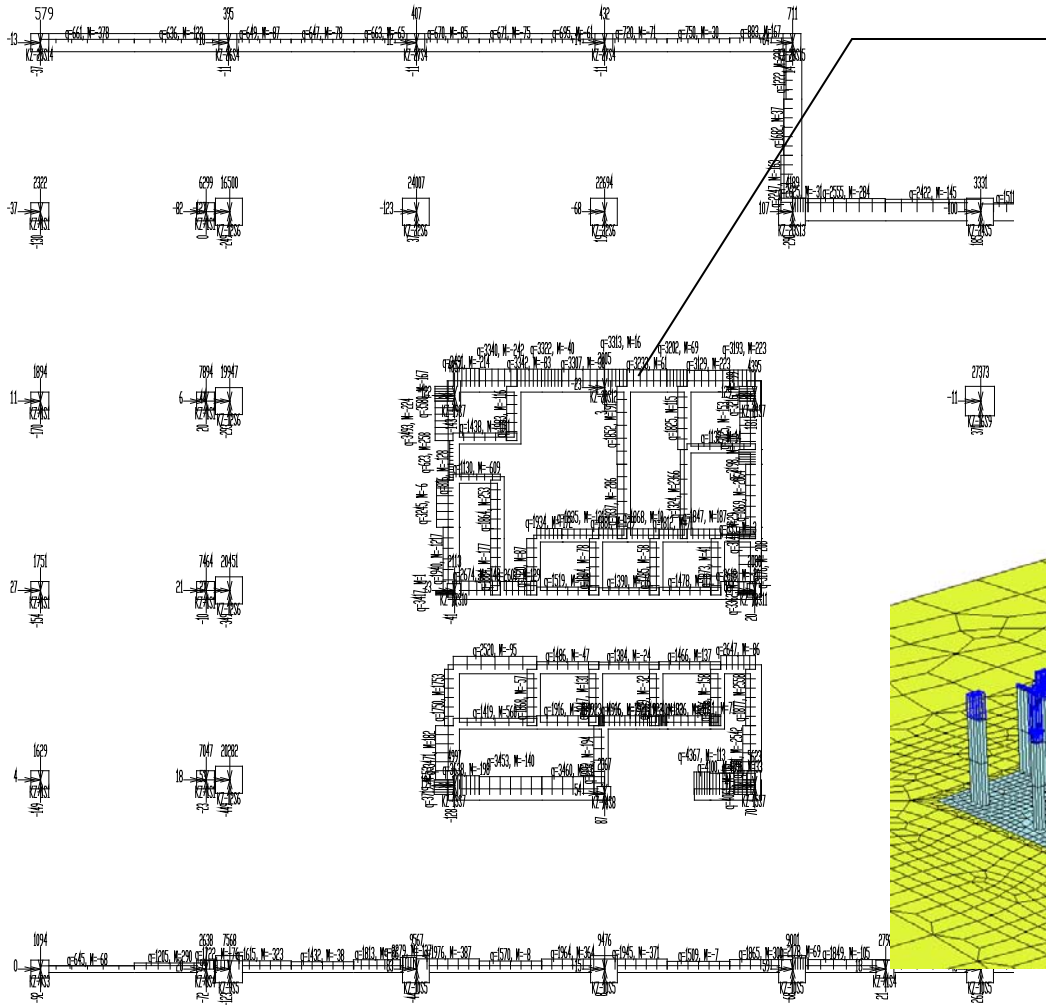
Practice of Pile Foundation treatment

3D FEM analysis

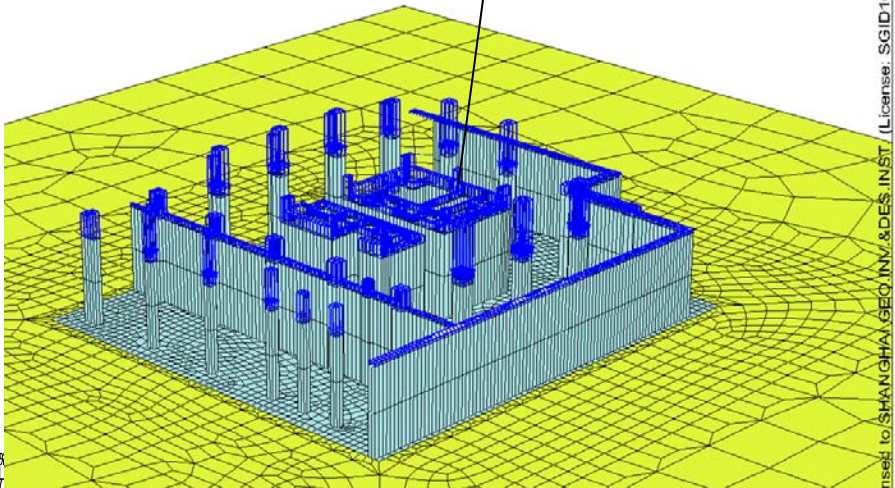
- We implement the below when establish FEM model
 - Pile element is used to model PHC pile. Pile skin and toe interface are considered.
 - The length of pile is set according to the construction record. For the convenience of modeling, piles are classified to 7m, 5m and 3m shorter than design value.
 - Borehole method is used to determine the spatial distribution of soil layer.
 - Mohr-coulomb model is used to describe soil mechanical behavior.
 - The geometry of frame column and shear wall is set strictly according to the structural design.
 - The load applied to frame column and wall is set strictly according to the structural analysis result.

Practice of Pile Foundation treatment

3D FEM analysis



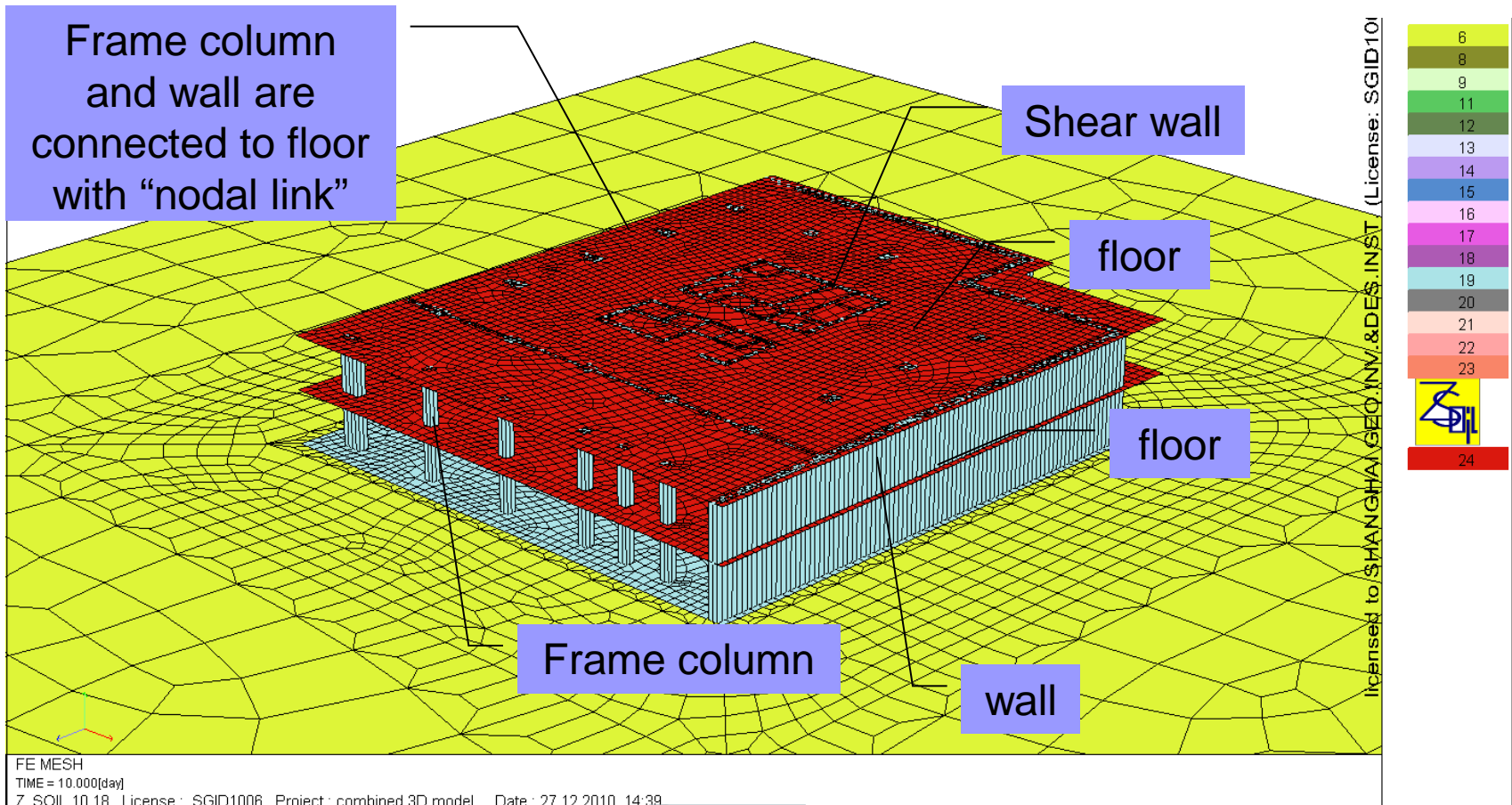
Load applied on wall and Frame column according to structural calculation result



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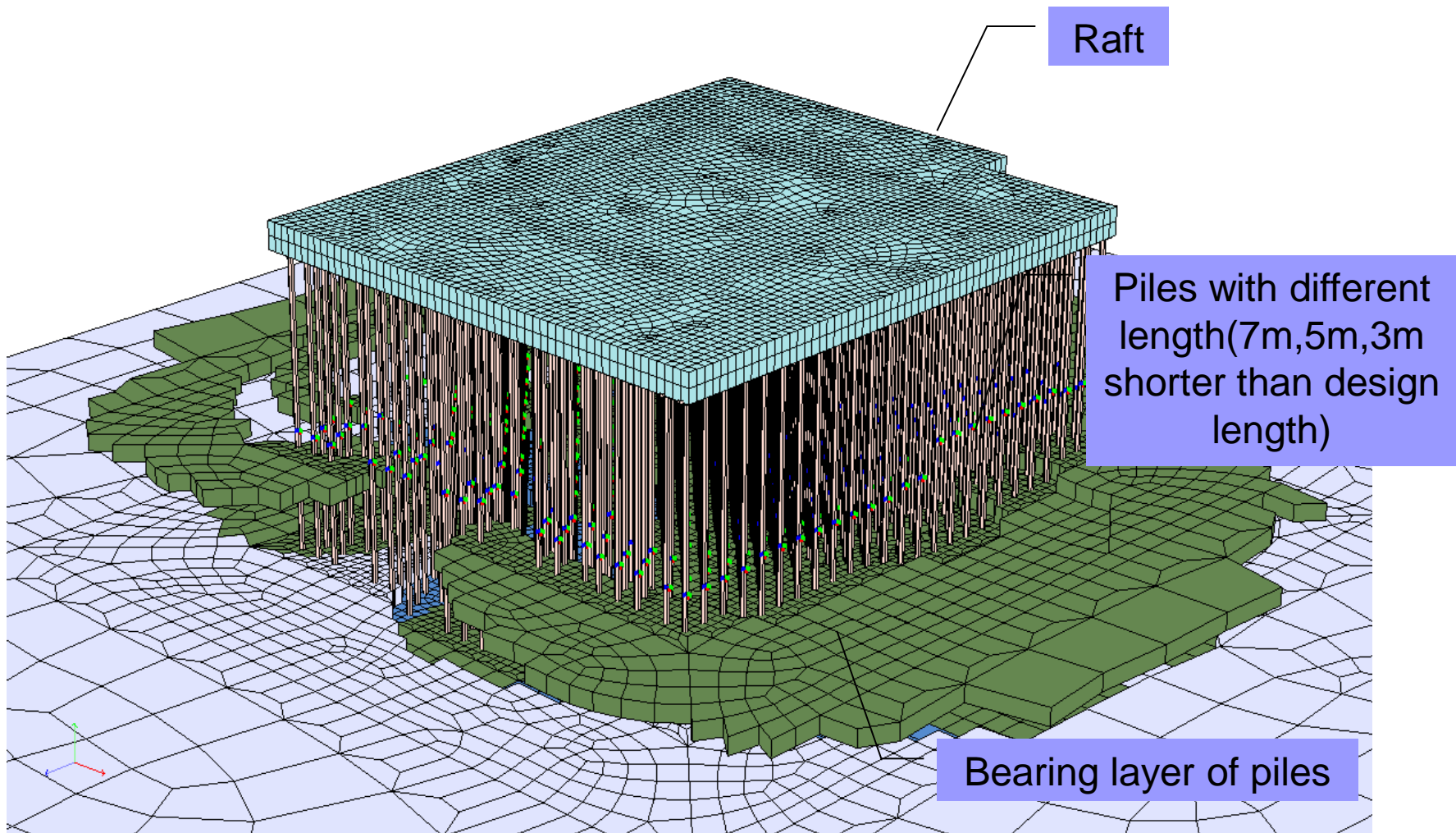
Practice of Pile Foundation treatment

3D FEM analysis



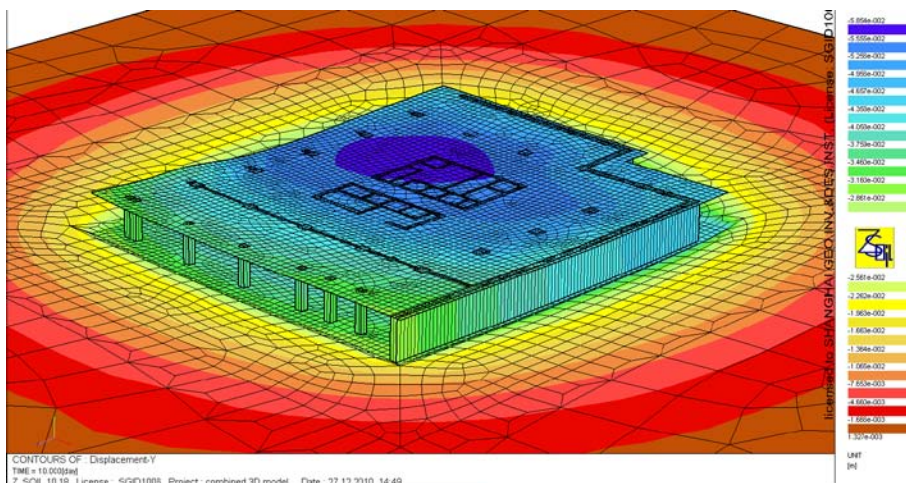
Practice of Pile Foundation treatment

3D FEM analysis

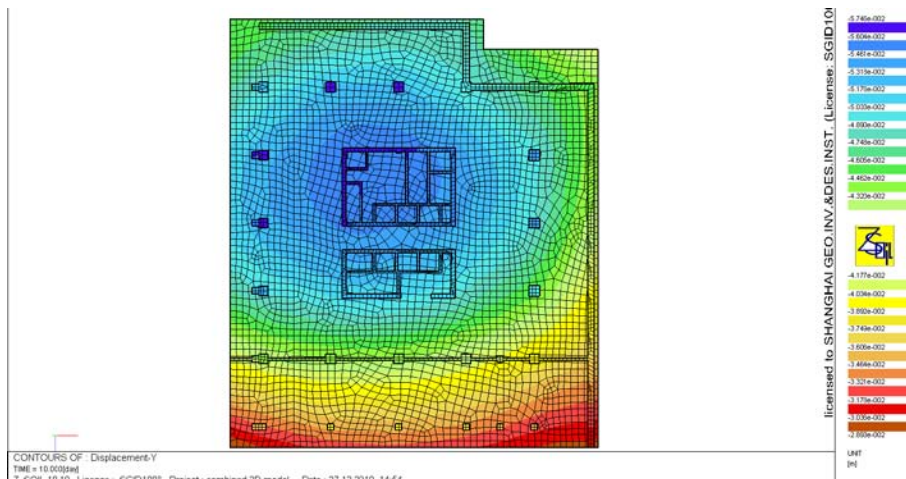


Practice of Pile Foundation treatment

3D FEM analysis

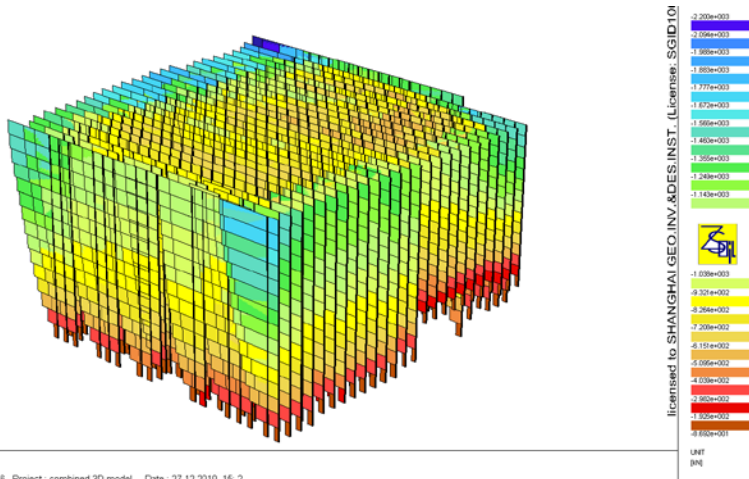


- Max. settlement is about 5.85cm, which occurs at the corner of the shear wall core tube.
 - This maybe the result of piles of different length and irregularly spatial distribution of bearing layer.
- Min. settlement is about 2.90cm.
- Max. settlement difference is about 2.95cm.
 - Taking into account the width of the raft(30m), the inclination of the building is about 0.1%.
- The max. settlement and the inclination of the building meet the requirements of the standard (GB50007-2002) .



Practice of Pile Foundation treatment

3D FEM analysis

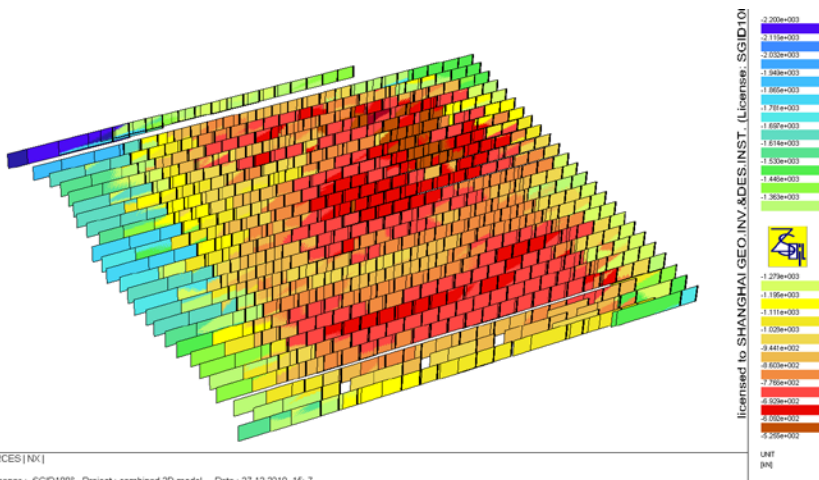


- Axial force of pile head range from 520 to 2200kN. The average value is about 950kN.

- According to the pile static load test, the calculated axial force of pile head (working load) is **below the bearing capacity(2375kN)**.

- The distribution of axial force of pile head is very different from our experience.

- According to our experience, max. axial force of pile head usually occurs at corner and edge of the raft.
- This maybe the result of piles of different length and irregularly spatial distribution of bearing layer.



Practice of Pile Foundation treatment












3D FEM analysis

■ Analysis Summary

- According to 3D Fem analysis, the bearing capacity of short piles, the settlement and inclination of the building can meet the requirement of Chinese foundation standard (“code for design of building foundation” GB50007-2002).
- It is necessary to conduct **super structure-foundation-soil interaction analysis** for irregularly spatial distributed soil layer and piles with different length.
 - Sometimes, experience from horizontally stratified ground can not be transplanted to irregularly spatial distributed soil layer.
- It is too conservative to design pile foundation without consideration of the contribution of raft.
 - With the help of the method mentioned above, we can optimize the design of pile foundation.

Acknowledgements

- Thanks to the development team of ZSOIL.PC
 - help from ZACE since 2011/01/03

<input type="checkbox"/>	ZACE	 Re: zsoil.pc v2011, BUG REPORT??	2011/6/18
<input type="checkbox"/>	 ZACE	 Re: about Softening MC model , zsoil.pc v2010/v2011	2011/6/13
<input type="checkbox"/>	ZACE	 Re: about Softening MC model , zsoil.pc v2010/v2011	2011/6/13
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<input type="checkbox"/>	 ZACE	 Re: Need help from zace, ZSOIL.PC v2010	2011/5/25
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<input type="checkbox"/>	 ZACE	 Re: About "Permeability" of 1-layer shell element, ZSOIL.PC V2010	2011/5/6
<input type="checkbox"/>	ZACE	 Re: About "Permeability" of 1-layer shell element, ZSOIL.PC V2010	2011/5/4
<input type="checkbox"/>	ZACE	 Re: ABOUT BOREHOLE OF ZSOIL.PC (III)	2011/3/3



- For some reasons, not all of the details is published in the PPT.
- Ideas maybe important than numbers for geotechnical engineers.



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