”FRESH TAKE” ON AN OLD TECHNOLOGY
Construction area bounding and foundation reinforcement with megapile and nailed slope surface protection

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ABSTRACT:
Nowadays, it is a constant engineering task on metropolitan constructions to secure the sidewalls of the pits and to lower the foundations of existing buildings. The work space bounding technologies used in everyday practice are mostly space demanding and expensive.
This method is an economical and quick solution for reinforcing foundation structures and bounding the construction area. In addition to a brief introduction to the technology, our presentation also contains a report on our research on megapile design.
The aim of that research is to process the data of static test loads recorded during the construction of the megapiles already designed by us and compare it with pile load capacity determined from cone penetration test results during the design. The expected result of our research is to develop a technological multiplier for the given technology to determine the load bearing capacity of megapiles through back analysis.

Keywords: pile; megapile; area bounding; foundation reinforcement; CPT

1. Introducing the megapile

As the title suggests, this technology is not new in Hungary.

It can only be used to reinforce the foundation of existing structures, since the counterweight for the piling of the elements into the soil is provided by the weight of the structure to be reinforced.

1.1. Application in the past

The technology was used to reinforce the foundation structures of sunken structures and, in extreme cases, to lift the structures into place.

The piles are made of precast reinforced concrete elements 60-80 cm long, 25x25 or 30x30 cm. The centering of the elements was ensured by steel pipe or a piece of reinforcing bar.

Precast elements are pressed into the ground by a hydraulic press under the existing foundations.

At the bottom of the pile, the peak moves forward, and once completed, a head member connects to the structure through two support elements and a load distributing member. [2]

1.2. The megapile technology

The technology we use is similar to “steel pipe pile press” method. The technology differs mainly in the material of the elements and in the design of the head unit.

During the extrusion, steel pipes are used instead of the precast reinforced concrete elements. The joints of the pipes are secured by welding.

The elements used in our research are illustrated in Fig. 1.

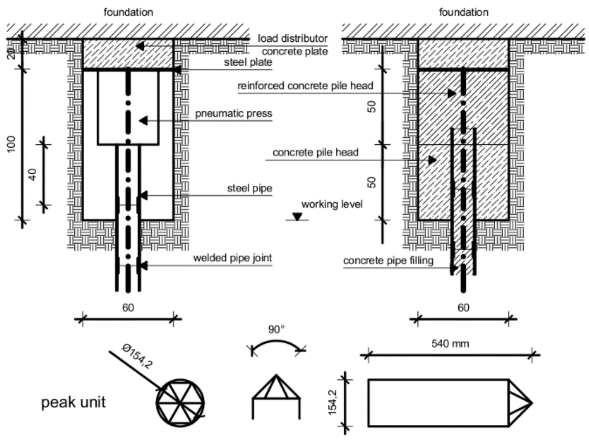

Figure 1. Work place on the left, completed pile head on the right and the unique peak element on the bottom

When the extrusion is completed, we fill the tubes with concrete, then create a monolithic reinforced concrete pile head.

The piles thus formed are capable of transmitting much of the load from the foundation level to a deeper level.

1.3. Workspace delimitation

The piles alone are only capable of carrying vertical loads and can’t carry horizontal ground pressure generated by excavation work.

Soil nailing combined with shotcrete slope protection are used to absorb horizontal loads and provide protection against spill.

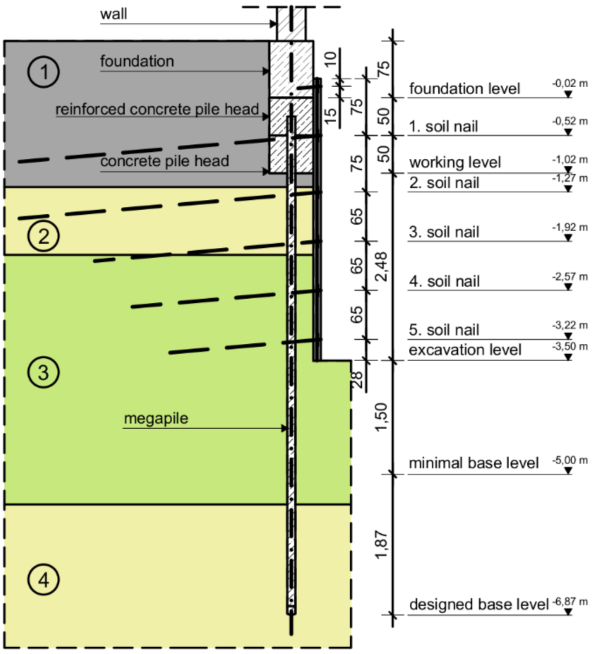

Figure 2. Cross section of the construction area bounding.

The combination of the aforementioned system provides a cost efficient and fast solution for vertical wall work pits in closed-row installation up to a depth of nearly five meters.

Advantages of the system:

- rapid execution due to prefabrication
- well controlled construction as a result of measurable pile strength and continuous motion testing
- small workplace requirements, low staffing
- slim, economical structures
- small loss of useable area
- piles can be made from the basement of the building
- can be made in parallel with other construction processes

Limitation of the system:

- not applicable for deep pits, up to 1 basement level
- depends on the weight and condition of the building to be reinforced
- depends of the groundwater level of the construction

2. Presentation of the Design task

Our company was commissioned to develop a work space delimitation plan to 8 Hubay Jenő Square, 15th district, Budapest.

2.1. Workspace delimitation concept

The planned basement pit is 3.5 m deep, its contour line is the same as the land boundary except on the western side of the area.

An existing building is connected to the planned building in 3 sections. Two on the west side (blue) and one on the east side (green). The eastern is a 3-storey brick-walled building of 6 dilatation units, length of the building is 120 m. The foundation levels of the connecting buildings vary by dilatation unit.

The reinforcement of the basement parts of the building is designed by sectional sub-concreting, the non-basement parts of the building were designed using the megapile technology presented above. We used soil nailing on the street facing sections.

Through the back analysis we examined the D-D and E-E sections shown on Fig. 3.

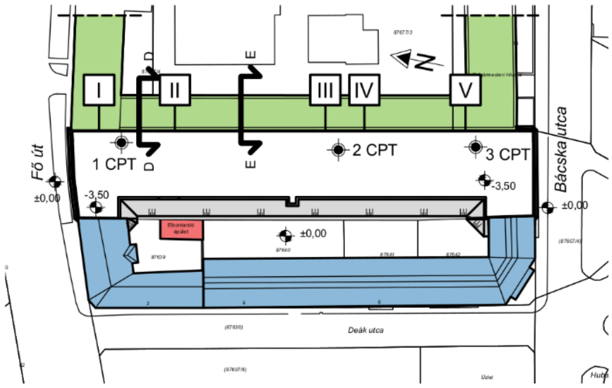

Figure 3. Site view

2.2. Description of the geotechnical characteristics of the area

For designing, we used the Soil and Geotechnical Report provided as a data service, and we deepened 3 additional CPTu probes in the area for designing the piles.

The terrain level (± 0.00) is at 111.12 Bm. The standard groundwater level was taken into account at 109.3 Bm, and during the excavation work the groundwater level was detected at 4.6 m.

The soil structure revealed by drilling and probing corresponds to the fluvial sediments deposited by the Danube River on the eastern riverside.

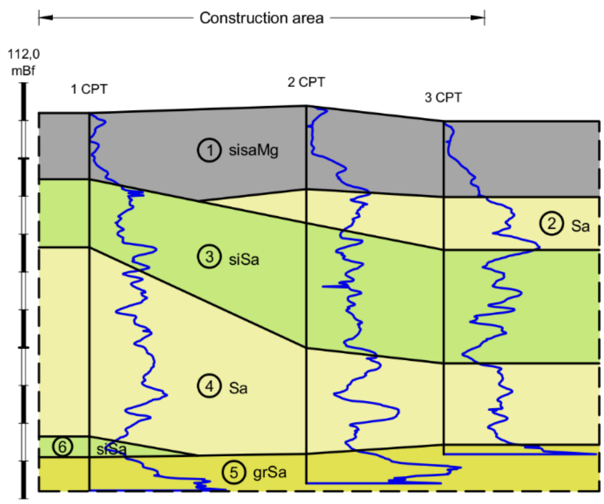

Figure 4. The layer of the soil at the construction area

The surface is covered with 2.1 to 2.7 m brown, gravel scattered, humus-filled sand (orgsaMg), which is of heterogeneous composition, of medium dense, dense state.

Between 2.1 and 3.2 m, yellow / yellowish gravelly sand (Sa) was found under the filling, which is moderately dense according to archival probing experience.

Below the sand, there is a gray / yellowish silty sand (siSa) at a depth of 3.1 to 6.3 m, which is a medium dense, saturated subsoil.

In the depth range of 6.3 to 9.8 m, gray / grayish-brown slightly silty medium sand (MSa) was drawn by drilling, which is a dense, saturated layer.

The bottom layer's top is at approx. 9.0 m deep, it consists of grayish-brown / brown gravelly Sand (grSa) and sandy Gravel (saGr), which is dense, high-strength layer.

3. Presentation of research

3.1. Determination of bearing capacity of megapile

During the extrusion of the piles, the supporting force is provided by the weight of the building to be strengthened. For the safety of structures, we examined the pile resistance in two states.

To determine the compression force during the extrusion we took into account the side resistance along the total length of the pile in the first strength state.

For the final bearing capacity state, the side resistance was calculated only between the pile's base level and the bottom of the pit. Through both the design process and our research we calculated the resistance of piles by a method of using filtered cone resistance from Cone Penetration Test results. [1]

In the research we calculated the resistance of the CPT model piles for the same base levels as the reports recorded during the construction work.

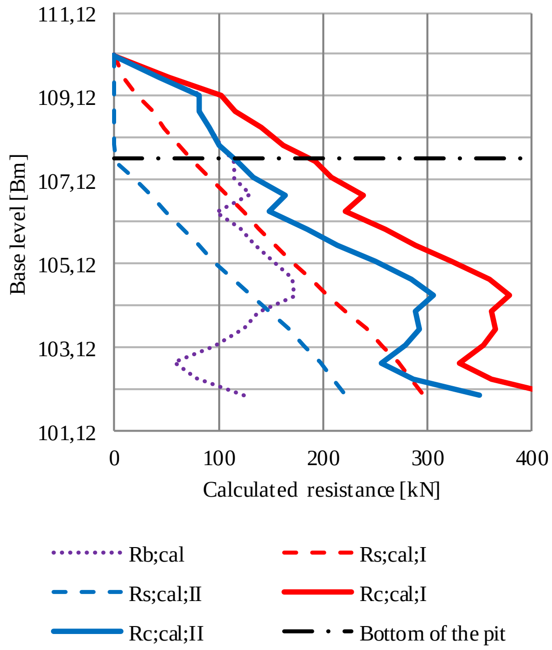

Figure 5. 1 CPT model pile's calculated resistance components in the designed E-E section

On Fig. 5. the we show the calculated resistance components of the 1 CPT model pile in the E-E section. The dashed lines show the side resistance ($R_{s;cal}$), the dotted line shows the base resistance ($R_{b;cal}$) and the continuous lines show the total pile resistances ($R_{c;cal}$) in the two examined strength states.

The designed level of the pile base was determined by the correlation of model piles through the correlation we used a partial factor of temporary state (γ=1,1) to get the design value of the pile resistance ($R_{c;d}$).

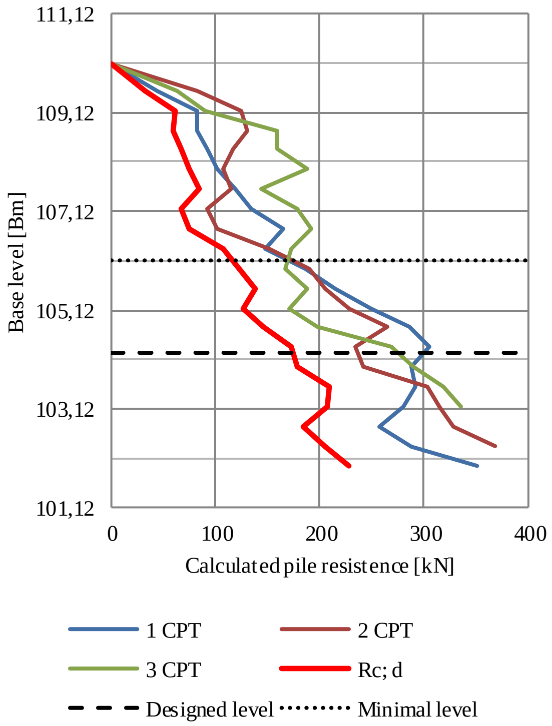

Figure 6. The result of the correlation of 3 model piles in the E-E section for the final strength state

The designed base level is -6,87 m (104,25 Bm), and the minimal base level is -5,00 m (106,12 Bm), determined from the geometry of the excavation. Fig. 7. shows the pile resistance during the extrusion.

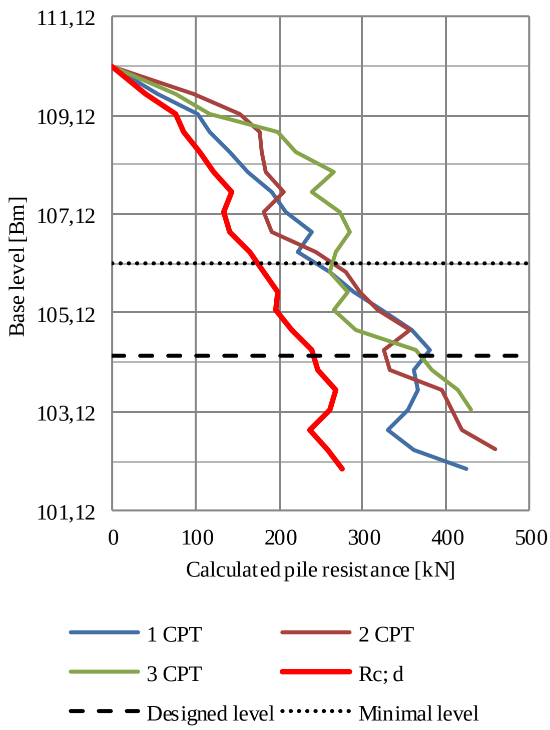

Figure 7. The result of the correlation of 3 model piles in the E-E section for the extrusion work state

3.2. Pile extrusion reports recorded during the construction work

During the construction the contractor recorded the data listed below for all piles:

- sign of the pile
- date of construction
- foundation level of the building
- compression force during the extrusion for every unit (every 40 cm-s)
- the final length and resistance of the pile

In the paper we present the statistical evaluation of 28 pieces in the D-D section and 47 pieces in the E-E section, totally 75 pieces of reports. We present mostly only the E-E section in details.

3.2.1. Recorded base level of the constructed megapiles

The constructed piles didn't reach the the designed base level (104,25 Bm), moreover 10 piles reached their maximal compression force (340 kN) over the minimal base level (106,12 Bm), as you can see on Fig 8.

The weighted average base level of the constructed 75 piles is -5,61 m (105,51 Bm).

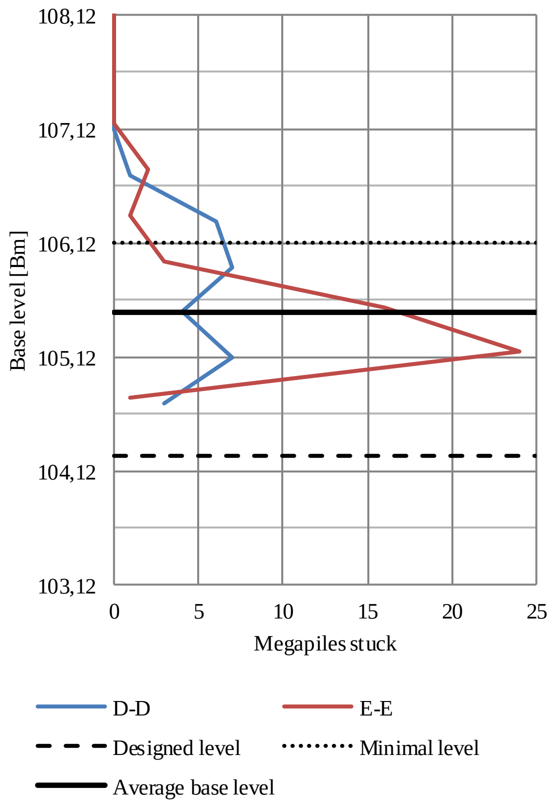

Figure 8. Reached base levels of the constructed piles

3.2.2. Recorded resistance of the construct-ed megapiles

On Fig 9. we visualized the resistance of the constructed piles for every recorded levels in the E-E section.

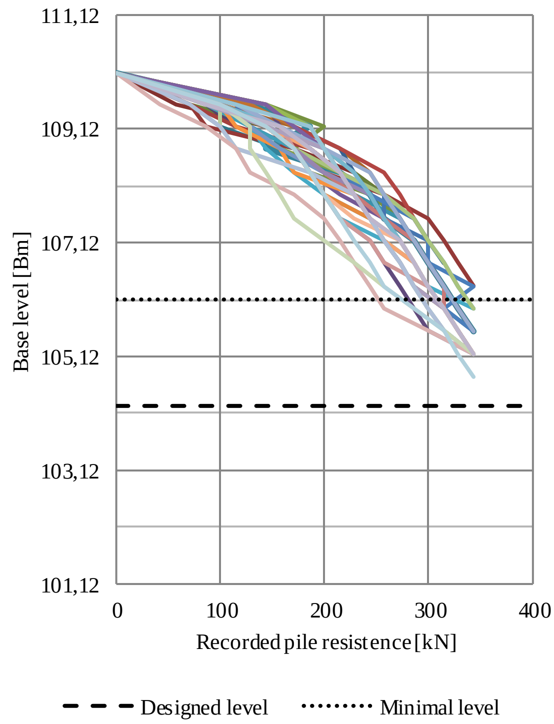

Figure 9. Recorded pile resistance data from the E-E section

During the statistical evaluation of the recorded data, we calculated the minimum (R_{min}), the maximum (R_{max}), the average (R_{mean}), the standard deviation and the 5% worst load capacity (R_{char}) for every base level. The result of the evaluation is presented below on Fig. 10.

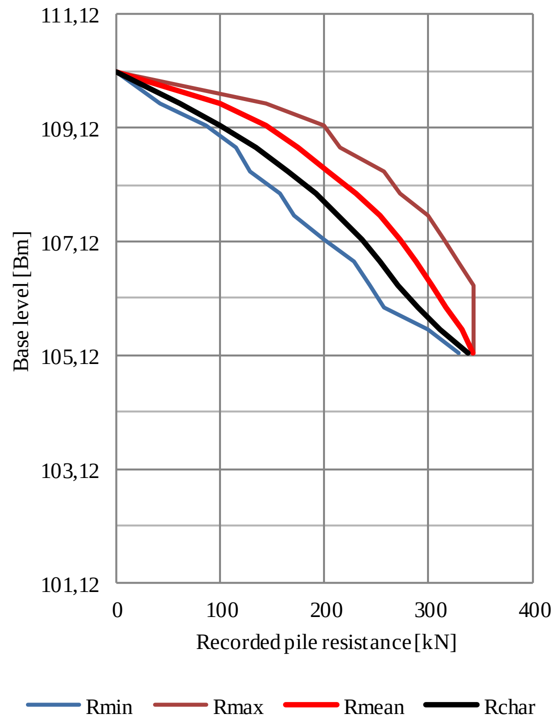

Figure 10. Result of the statistical evaluation

3.3. The result of back analysis

We calculated the factor of safety for the average (R_{mean}) and the characteristic pile resistance (R_{char}) by dividing both with the designed value of pile resistance ($R_{c;d}$) for all recorded base levels. The average value of these factors from the examined sections are presented below in “Table 1.”.

Table 1. Safety factors of pile resistance calculation in the examined sections

section	γ_{mean}	γ_{char}
D-D	2,00	1,52
E-E	1,92	1,59

As we expected the results were pretty much the same in the examined sections.

4. Conclusion

4.1. The negative effects of over engineering

To avoid lifting the building, the technology introduced in the 1.2. chapter doesn’t provide the freedom to overdesign the megapiles by the safety factor of 2,0 – 2,5 times commonly used in pile designing. Overdesign is unreasonable, because the the pile resistance is continously measureable during the construction.

It is important to acurately determine the appropriate diameter of megapiles to provide the necessary cover over the pile’s peak. If this is not ensured in an execution, the required resistance can be achieved by the piles above the minimal base level.

It is important to predict with better accuracy the required length of megapiles from an economic point of view.

4.2. Recommendation

Based on the results of the back analysis, in a case similar to the soil environment presented in Section 2.2 (dense to moderately dense sandy soils). We recommend to multiply the design value of the calculated pile resistance ($R_{c;d}$) by β_{mega} = 1,5 correctional factor, to provide a more precise method to determine the required pile diameter and base level.

In this case, the density of probing and boring is still taken into account in the calculation of pile resistance.

As a result of multiplication by the β_{mega} correctional factor, the modified design value of pile resistance ($R_{c;d;\,mod}$) will be close to the expected characteristic pile resistance (R_{char}), which corresponds to the 5% worst load capacity of the constructed piles.

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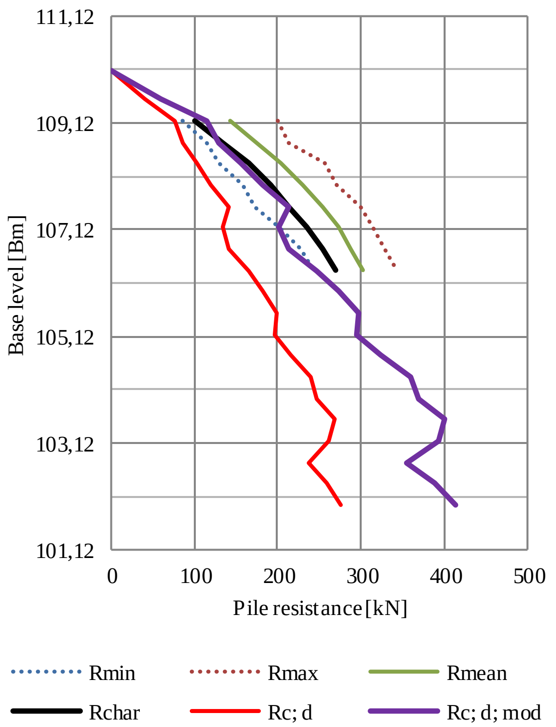

Figure 11. The modified design value of calculated pile resistance

References

[1] R. Szepesházi “Cölöpalapok méretezése az Eurocode 7 követelményei szerint” / “Pile design based according to the requirements of Eurocode 7”, University of Miskolc, 2011

[2] S. Bartos, B. Králik, “Mélyépítés III. (Alapozás)” / “Civil Engineering III. (Foundation)”, Nemzeti Tankönyv Kiadó, Budapest, Hungary, 1995

[3] Z. Szabó, “Talajvizsgálati és geotechnikai jelentés a Budapest, Hubay Jenő tér 8., HRSZ.:87643 ingatlanon tervezett épület talajmechanikai vizsgálatáról” / “Soil Investigation and Geotechnical Report of property located at Budapest, Hubay Jenő tér 8., HRSZ.:87643”, Muszasi Kft., Úrhida, Hungary, 2018.

[4] E. Horváthné Bak, G. Berki, G.Bíbok, Z. Kőhalmi, “Budapest, XV. kerület, Hubay Jenő tér 8. 60 lakásos társasház tervezéséhez, érintett épületek alapmegerősítési terve, kombinált munkaté-rhatárolási tervdokumentáció” / “Affected buildings foundation reinforcement plan and combined workspace delimitation plan of a 60-apartment condominium at Budapest, XV. kerület, Hubay Jenő tér 8.”, FTV Geotechnikai, Geodéziai és Környezetvédelmi Zrt., Budapest, Hungary, 2018.

Remark: Refference titles style: “Hungarian-native” / “English-translated”