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The concept of pile foundations calculation and design

Adam Krasiński, Piotr Bergius
Gdansk University of Technology, Faculty of Civil and Environmental Eng., Gdansk, Poland, adam.krasinski@pg.edu.pl

ABSTRACT: This paper presents a conceptual approach to pile foundation design, where pile bearing capacity is defined by its load-settlement (*Q-s*) characteristic. The traditional ultimate pile capacity in [kN] plays a secondary, formal role. The nonlinear *Q-s* curve, obtained by any analytical, empirical, or numerical method, is simplified into a bilinear diagram described by three parameters. A method to modify the pile characteristics, considering pile group interaction, is also introduced. Static analysis of pile foundations, typically done using computer software for complex structures, evaluates the foundation under serviceability (SLS) and ultimate (ULS) limit states. Displacements, deformations, and stresses in the superstructure are key factors influencing load distribution in piles. Verification of the GEO limit state for pile bearing capacity can be practically omitted as it is inherently included in the calculation. This method is especially useful for designing foundation slabs, grid beams and bridge supports. Two calculation examples demonstrate that the approach improves design safety and can provide economic benefits, such as reduced pile lengths, compared to traditional methods. Additionally, a revised, simpler and clearer interpretation of pile load tests is proposed to replace existing practices.

KEYWORDS: Piles, pile foundation, pile calculation and design, settlement characteristic of pile.

1 INTRODUCTION

Pile foundation calculations generally involve determining pile forces for various load combinations and verifying the ultimate limit state (ULS) and serviceability limit state (SLS) conditions. Structural calculations are the next stage, mainly for the foundation cap and piles in order, among other things, to determine their reinforcement. Such and similar calculation methods have been presented in many publications, including e.g.: Poulos & Davis (1980), De Cock et al. (2003).

The computational phases described are usually disconnected and often implemented using a single calculation scheme applying various combinations of characteristic and design loads. Piles are differently modelled in this scheme, but still very often with linear *Q-s* characteristics, identical for all piles and the same for both the SLS and ULS limit states. The described calculation and design approach has several shortcomings. Firstly, it does not accurately reflect the actual interaction between piles and soil, secondly, it is inflexible and inefficient and thirdly, it does not fully utilize the capabilities of modern calculation techniques. As a result, this approach can lead to overestimation of piles (their number or length) and underestimation of the foundation cap structure.

In this article, the authors propose an approach to calculating pile foundations that considers the pile's bearing capacity not as a numerical value R_c, expressed in [kN], but as a load-settlement characteristic *Q-s*, expressed as a function or graph. In parallel, a different approach is proposed for analysing the results of pile foundations static calculations and for evaluating the results of pile load tests. Two calculation examples demonstrate that the proposed calculation approach is valid and can bring benefits.

2 IDEA, ASSUMPTIONS AND PROCEDURE OF THE PROPOSED COMPUTATIONAL APPROACH

The basic idea of the proposed calculation approach is to replace the concept of pile bearing capacity as a specific numerical value R_c or R_t expressed in [kN] with a load-settlement characteristic of the pile *Q-s*. The outlines of this approach have already been presented in Krasiński (2015) and Gwizdała & Krasiński (2016). This method of considering pile bearing capacity is more transparent, unambiguous, and universal than the previous, classical one. This is evidenced by comparisons of the *Q-s* diagrams presented in Figure 1. Figure 1a shows two piles, 1 and 2, with theoretically the same ultimate bearing capacities $R_{c;cal}$, but with significantly different shapes of the settlement diagrams. Figure 1b shows two piles, 3 and 4, with clearly different $R_{c;cal}$ bearing capacities and *Q-s* diagrams.

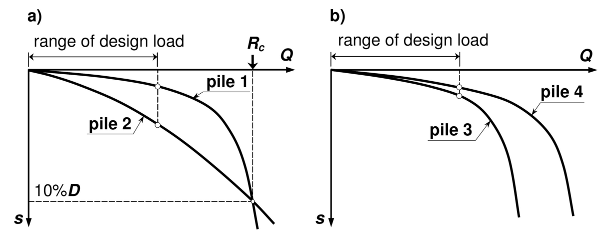

Figure 1. The idea of defining (expressing) the load-bearing capacity of piles using settlement curves.

3 *Q-S* CHARACTERISTICS OF PILES

3.1 *Q-s characteristic of a single pile and its simplification*

The basis of the entire computational approach discussed here is the reliable determination of the nonlinear load-settlement characteristic of piles (*Q-s*). The literature offers numerous proposals in this matter. This can be accomplished using analytical methods, e.g. transfer functions (e.g. Gwizdała, 1996), empirical formulas derived from numerous pile load tests and associated with in-situ tests (CPTU, DMT, PMT, SPT) (e.g. Krasiński, 2013, Bohn et al. 2016, Fellenius, 2018) or numerical FEM methods (e.g. Krasiński, 2014). Due to space constraints, a discussion of these methods is omitted in this paper. It is only noted that the shape and parameters of the *Q-s* characteristic depend on many factors, but primarily on soil conditions, pile construction technology and pile geometry: diameter D and length L. In some methods (mainly analytical), the *Q-s* characteristic of pile is closely related to its ultimate load-bearing capacity R_c.

Depending on the capabilities of the static calculation program, the pile characteristics can be defined using a continuous (nonlinear) function or using a bilinear graph, described by three parameters: K_1, K_2, and d_1, as shown in Figure 1. The bilinear graph is more convenient and in most cases fully sufficient for design and engineering purposes. The shape of the bilinear diagram can be selected to best fit the course of the original diagram, but it is best if the value of force Q_1 is selected so that it is slightly greater than the average characteristic load Q_k per single pile in the analysed foundation.

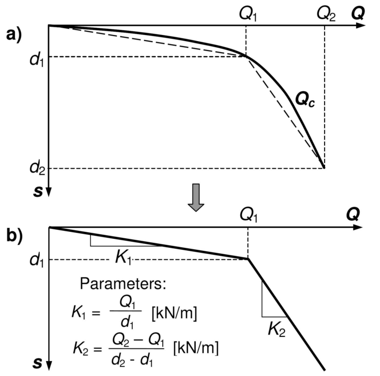

Figure 2. Replacing the continuous *Q-s* characteristic of the pile with a bilinear diagram.

3.2 *Q-s characteristics of piles in a group*

Determination of load-settlement characteristics of piles in a group is a complex issue. Two phenomena influence the characteristics:
1) The interaction of adjacent piles, which depends primarily on the pile spacing and length.
2) The settlement of the soil beneath the entire pile group, which depends on the load on the entire foundation and the size (dimensions) of the pile group.
Both of these phenomena are not well researched yet and adequately and clearly described for practical purposes (computational and design). They are currently being studied by the co-author of the article, P. Bergius, as part of his doctoral dissertation.

Ad. 1) The effects of mutual interaction of adjacent piles are shown schematically in Figure 3. It shows that in the initial loading phases (more or less within the design load range), the settlement of a pile in a group is greater than that of a single pile, while at higher displacement values the pile in a group is strengthened compared to the single pile.

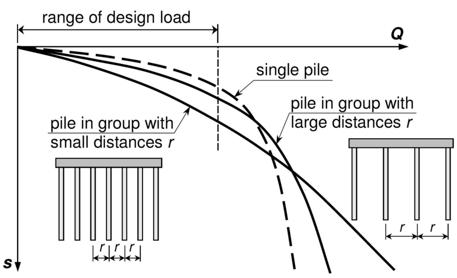

Figure 3. The influence of pile spacing on the *Q-s* shapes of piles in the group.

More generally, a pile in a group has a lower initial stiffness but a higher ultimate load-bearing capacity than a single pile. This can be explained by the increased overall stress level in the soil around the pile in a group compared to a single pile. This leads to an increase in frictional resistance in the soil, on the one hand, and an increase in soil deformation (settlement), on the other hand. The smaller the spacing *r* of the piles in a group, the greater the difference in the characteristics of the pile in the group and of single pile, as also shown in Figure 3.

Based on the results of numerical analyses (MES), a proprietary, simplified method for determining the *Q-s* characteristics of a pile in a group based on the characteristics of a single pile was proposed in Krasiński (2022). For simplicity, this method was developed for a bilinear diagram, as conceptually presented in Figure 4. This method is based on the m_1 coefficient, which depends on the relative spacing of piles in the group r/D and the relative depth of piles in the load-bearing layers h_{pN}/D. The proposed values of the m_1 are given in Table 1. The entire method requires verification through tests on actual piles using various technologies, which is the subject of research by P. Bergius as part of his doctoral thesis. The values m_1 given in Table 1 can be considered safe.

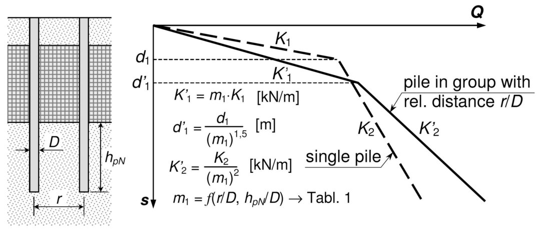

Figure 4. Proposal for converting the bilinear *Q-s* characteristic of a single pile into a pile in a group using the m_1 coefficient.

Table 1. Proposed values of the m_1 coefficient (Krasiński, 2022).

r/D	8			6			4		
h_{pN}/D	3	5	10	3	5	10	3	5	10
m_1	1.0	0.95	0.9	0.95	0.9	0.8	0.85	0.75	0.8

The values of the m_1 coefficient given in Table 1 refer to piles located within a pile group. For edge, corner and linear piles, these coefficients should be corrected using the following formulas (Krasiński, 2022):

– edge piles: $m_{1;e} = 0{,}25 + 0{,}75 \cdot m_1$ (1)

– corner piles: $m_{1;c} = 0{,}5 + 0{,}5 \cdot m_1$ (2)

– internal piles in the linear group:

$$m_{1;l} = 0{,}5 + 0{,}5 \cdot m_1 \quad (3)$$

– edge piles in the linear group:

$$m_{1;s} = 0{,}75 + 0{,}25 \cdot m_1 \quad (4)$$

Ad. 2) The interaction of piles, described in point 1), concerned the soil zone located between the piles and extending to a depth of 4*D* below their bases (this was the assumed depth of interaction for each pile considered individually). The interaction of the entire group of piles is much deeper, as shown schematically in Figure 5a.

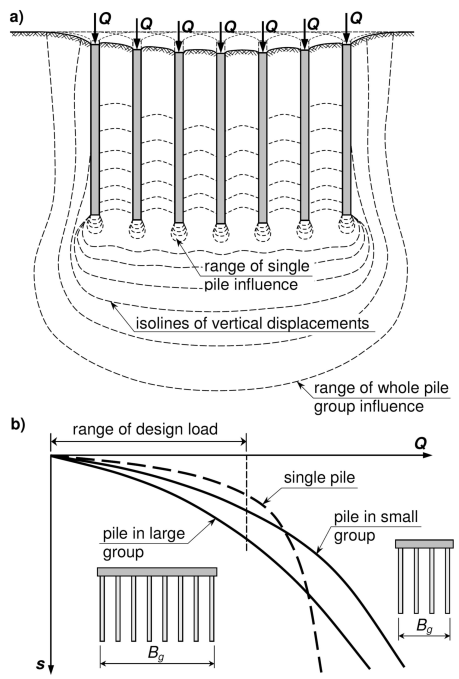

Figure 5. The influence of a pile group dimension on the settlement of the underlying soil and on the shapes of the pile *Q-s* characteristics.

This action causes settlement s_{pg} of the ground space under the pile bases, which can reach a depth equal to the width of the entire group B_g or more and can be several times greater than the settlement of a single pile (this depends on the deformability of the soil beneath the pile group). Settlement of pile groups is the subject of many publications, including: Randolph & Wroth (1979), Chow (1986), Poulos (1988), Gwizdała & Dyka (2002). The fact that settlements of piles in groups are much greater than those of individual piles has been confirmed by many measurements on real objects (e.g. Hemsley, 2000, Dembicki et al., 2013).

For the engineering purposes, calculations of settlement s_{pg} can be made using the deep equivalent foundation method, shown in Figure 6. It is proposed to assume the level of this foundation at a depth of $4D$ below their bases, and its dimensions B_e and L_e should be determined from generating lines drawn at an angle $\alpha = \phi'/2$ from the outer piles of the foundation. A similar procedure should be followed for a circular or strip-shaped pile foundation. To calculate the load value q_{pg} of the equivalent foundation, it is proposed to assume the approximate value of the total characteristic load of the foundation (e.g. $\sum Q_{i;k}$), reduced by the weight of the soil extracted from the foundation excavation.

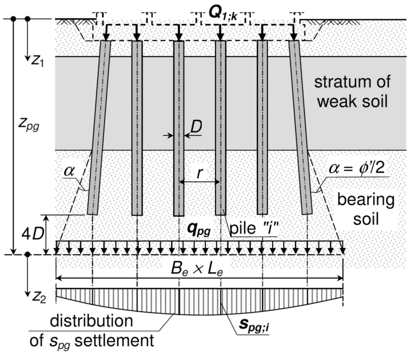

Figure 6. Example scheme for calculating the settlement of soil under a rectangular group of piles.

The calculations of settlement s_{pg} can be performed using any generally acceptable method, e.g. uniaxial deformation. For a rectangular area $B_e \times L_e$, the method of centre and corner points can be used. In order to increase the reliability of calculation results, it is suggested to take into account the increase in the soil compressibility modulus M_0 with stresses according to the formula proposed in EN 1997-2:2007:

$$M_0(z) = M_{0;ref} \cdot \left[\frac{\sigma'_{v0}(z_1) + 0.5\Delta\sigma'_v(z_2)}{p_{ref}}\right]^{w_2} \tag{5}$$

where:
$M_{0;ref}$ – reference value of the compressibility modulus corresponding to stress p_{ref} = 100 kPa,
$\sigma'_{v0}(z_1)$ – vertical component of the effective initial stress at depth z_1,
$\Delta\sigma'_v(z_2)$ – vertical component of the effective stress due to the structure load at depth z_2,
w_2 – exponent with a value of 0.5 for non-cohesive soils and 0.6 for cohesive soils.

The depth z_1 should be taken from ground level, and z_2 from the level of the equivalent foundation (Figure 6). According to EC7 recommendation, settlement s_{pg} should be calculated to depth z_2 at which the additional stresses $\Delta\sigma'_v(z_2)$ reach 20% of the initial stress $\sigma'_{v0}(z_1)$.
The settlement distribution s_{pg} is proposed to be described by the function $s_{pg}(x, y)$, which will allow for further determination of settlement values $s_{pg;i}$ under any pile "i". For a rectangular area $B_e \times L_e$ this function can be of the form:

$$s_g(x, y) = ax^2 + by^2 + cx^2y^2 + d \tag{6}$$

in which the coefficients a, b, c, and d are determined from the calculations of settlements at four characteristic points. The method presented here applies to the case of relatively uniform (parallel) deposition of soil layers under a group of piles. In other cases, the group can be divided into subgroups. Other methods of calculating the settlement of soil under a group of piles are also possible, such as the concentrated force method using Boussinesq's formula.
The final settlement characteristic of pile "i" in group $(Q\text{-}s)'_{g;i}$ will be the sum of the graph from Figure 4 and the settlement graph of the soil underlying the pile group, which was assumed to be linear (in reality it is slightly nonlinear). The method and result of this summation are shown in Figure 7. The $(Q\text{-}s)'_{g;i}$ characteristic should be determined for each pile in the foundation (pile group), as it depends on the pile location.

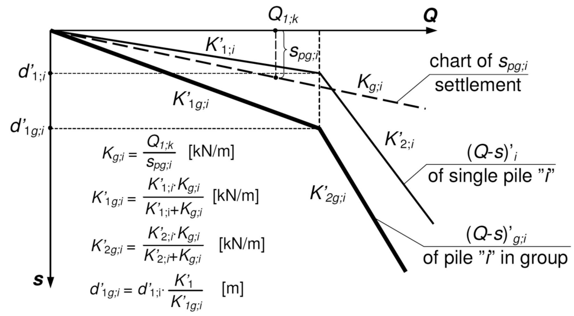

Figure 7. Scheme for calculating the final $(Q\text{-}s)'_{g;i}$ parameters for pile "i" in the group.

4 APPLICATION OF PILE (Q-S) CHARACTERISTICS IN PILE FOUNDATIONS CALCULATION

For static calculations, a calculation scheme for a pile foundation is prepared, in which the piles are represented either by single elastic supports with nonlinear characteristics $(Q\text{-}s)'_{g;i}$, or by bars (columns) interacting with the ground through a series of elastic supports, where the supports located beneath the pile bases have nonlinear characteristics $(Q\text{-}s)'_{g;i}$ (see the calculation examples). The choice of calculation scheme is left to the designer. Generally, under vertically loaded grids and foundation slabs, modelling piles with single elastic supports is sufficient.

The diagrams presented in Figure 7 should be considered the so-called calculated (preliminary) diagrams – $(Q\text{-}s)'_{g;i;cal}$. For complete calculations of the pile foundation and verification of the SLS and ULS conditions, two more diagrams should be prepared: the characteristic diagram $(Q\text{-}s)'_{g;i;k}$ and the design diagram $(Q\text{-}s)'_{g;i;d}$. The recommendations of EC7 should be used here. The method for determining these two diagrams is shown in Figure 8, where ξ_3 and ξ_4 are correlation coefficients, and γ_f is a partial factor for the pile bearing capacity, according to EC7.

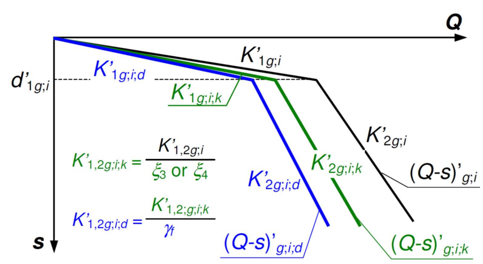

Figure 8. Calculation of characteristic and design pile Q-s diagrams for SLS and ULS calculations.

From the above, it follows that two separate calculation schemes for the pile foundation should also be prepared: the first for calculating foundation displacements and deformations, using characteristic pile stiffnesses $(Q\text{-}s)'_{g;i;k}$ and specified characteristic loads, the second for calculating internal forces in the foundation cap and in piles, using design pile stiffnesses $(Q\text{-}s)'_{g;i;d}$ and specified design loads determined using the appropriate γ_G and γ_Q coefficients (according to EC7).

In analysing the calculation results, verifying the SLS conditions, which concern displacements (settlements) and deformations of the foundation cap, and the ULS-STR conditions, which concern internal forces and the strength of structural elements, also in relation to the piles, plays a fundamental role. Verifying the ULS-GEO condition, which concerns the load-bearing capacity of piles in the ground, plays a secondary, more formal role in the discussed method.

5 CALCULATION EXAMPLES

5.1 *Example 1*

Example 1 concerns a grid beam consisting of 52 CFA piles, designed for the foundation of a typical general-purpose building. The pile foundation plan is presented in Figure 9, while Figure 10 shows the static scheme and layout of the external loads with their characteristic values.

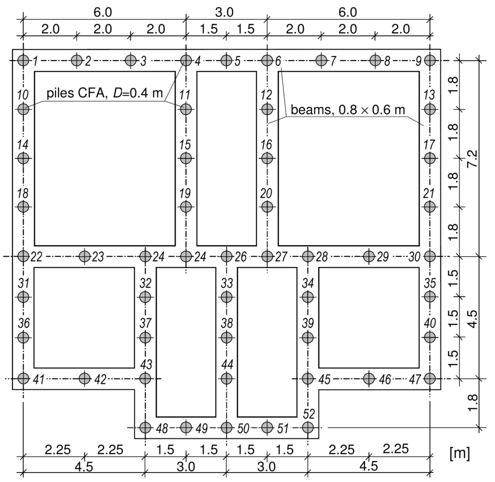

Figure 9. Pile foundation geometry for calculation of Example 1.

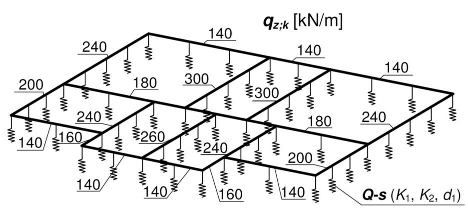

Figure 10. Static scheme of pile foundation with external loads.

Figure 11 presents the geometric parameters of a CFA pile on the background of a geotechnical cross-section determined on the basis of CPTU testing. In the same figure, the Q-s characteristic of the piles are shown, starting from the base nonlinear diagram of a single pile, through a simplified bilinear diagram of a single pile and ending with the final bilinear diagram of a pile in a group for the exemplary pile No. 20 (located in the central part of the foundation). The basic Q-s diagram was determined from CPTU test results using the method described in Krasiński (2014). The calculation of the soil settlement beneath the entire pile group s_{pg} was performed by replacing individual piles with concentrated forces and applying Boussinesq's formula together with the recommendations provided in Section 3.2. The resulting settlements ranged from 2.7 mm to 9.1 mm, with the smallest value observed under the corner piles and the largest under the central piles. Due to space limitations, the detailed calculation procedure is not presented in this paper.

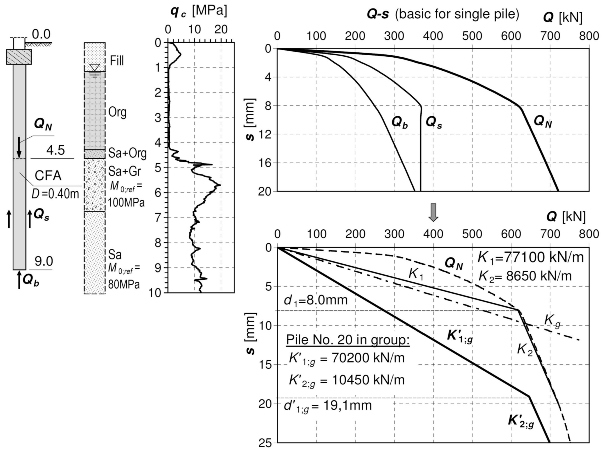

Figure 11. Results of pile Q-s characteristics calculations.

The structural analysis of the foundation was carried out using the Robot Structural Analysis software, adopting a grid beam model on elastic pile supports (Figure 10). For comparison, two variants of pile support characteristic were analysed. In Variant I, nonlinear (bilinear) characteristic of piles in a group were assumed, with parameters $K'_{1;g}$, $K'_{2;g}$ and $d'_{1;g}$ determined according to the procedure described in this paper. In Variant II, linear characteristic of single piles with the stiffness parameter $K = K_1$ were assumed. For both variants, calculations were performed for SLS and ULS conditions.

Figure 12 presents the SLS calculation results in the form of vertical displacements (settlements) of the pile grid beam. Numerical values are provided for both variants. Those given in brackets refer to Variant II. It can be observed that settlements in Variant I are more uneven and 2 to 3 times larger than in Variant II.

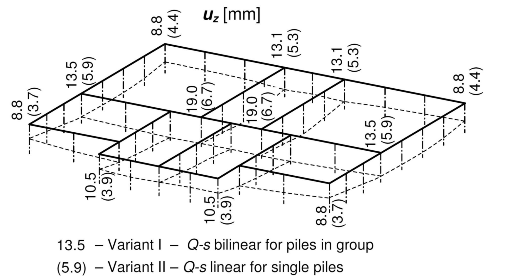

Figure 12. Pile foundation calculation results – vertical displacements for SLS.

Figure 13 presents the ULS calculation results in the form of pile forces with desing values. As in the previous case, the results are given for both variants. Those in brackets correspond to Variant II. It can be observed that, in contrast to displacements, the pile force values do not differ significantly (particularly the maximum forces). However, the authors have analysed cases where these differences were greater – ranging from 15% to 25% in favor of Variant I. These cases concerned foundations subjected to more concentrated and unevenly distributed loads. Figure 14 presents the ULS calculation results in the form of bending moment diagrams M_y in the grid beams. Values in brackets correspond to Variant II. Significant differences between the two variants can be observed. The maximum bending moments (highlighted in bold) in Variant I are approximately 40% higher than in Variant II. In other locations, these differences are even greater, and in some cases, the sign of the moment changes from negative to positive.

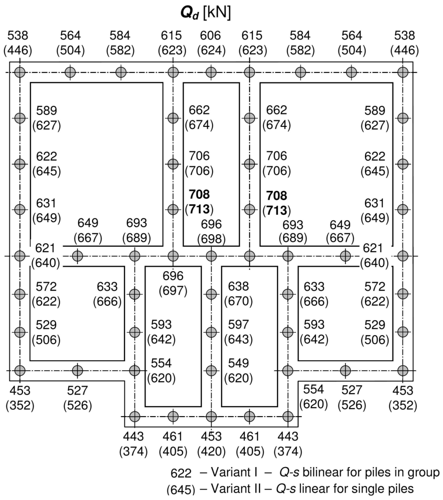

Figure 13. Pile foundation calculation results – pile forces for ULS.

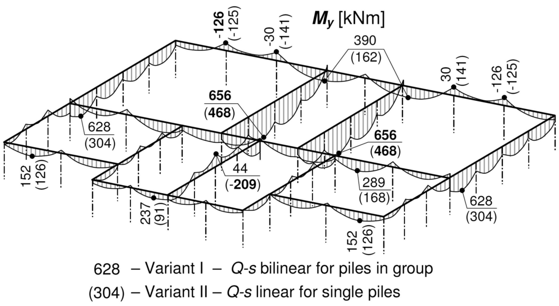

Figure 14. Pile foundation calculation results – bending moments in grid beams for ULS.

5.2 *Example 2*

Example 2 concerns the foundation of a bridge abutment supported on driven precast piles. The geometric layout of the abutment and pile foundation, including the applied loads and the geotechnical profile, is presented in Figure 15.

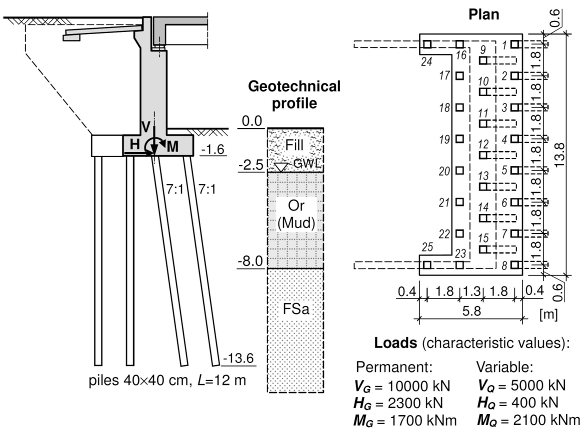

Figure 15. Pile foundation geometry for calculation of Example 2.

The *Q-s* characteristic of a single pile was determined using the transfer function method (Gwizdała, 1996) based on pile bearing capacity calculations in accordance with the Polish standard adapted to EC7 requirements (Gwizdała & Krasiński, 2016). The calculation of soil settlement s_{pg} beneath the pile group was carried out by assuming an equivalent rectangular foundation and applying the corner-centre points method. Due to the driven pile technology, the settlements s_{pg} were arbitrary reduced by half. The resulting settlements ranged from 2.1 mm under the corner piles to 3.7 mm under the central piles. The resulted *Q-s* pile characteristics for both a single pile and a pile in a group, are shown in Figure 16. For the same reasons as in Example 1, the detailed calculation procedure is not included in this paper.

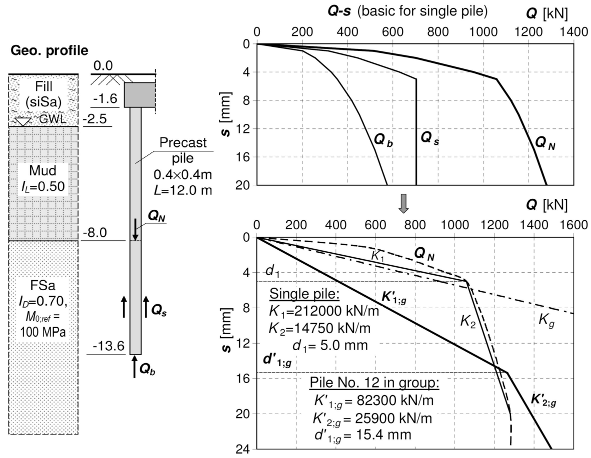

Figure 16. Calculated pile *Q-s* characteristics for Example 2.

In the structural analysis (Robot Structural Analysis software), the abutment and pile foundation were modelled such that the piles were represented as beam elements interacting with the soil medium through a series of elastic springs (Figure 17).

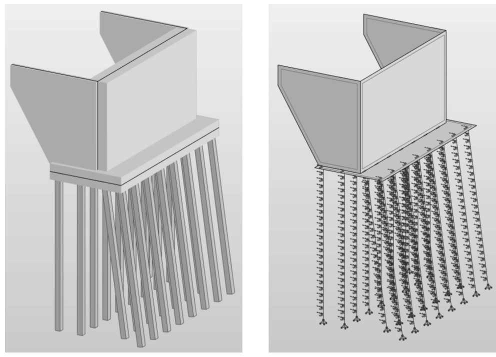
Figure 17. Structural scheme of bridge abutment on pile foundation.

As in Example 1, two variants of *Q-s* characteristics for the pile supports beneath the pile bases were analysed. In Variant I, nonlinear (bilinear) characteristics of piles in a group were assumed with parameters $K'_{1;g}$, $K'_{2;g}$ and $d'_{1;g}$. In Variant II, linear characteristics of single piles with stiffness $K = K_1$ were taken into account. For both variants, calculations were performed for SLS and ULS conditions.

Figure 18 presents the SLS and ULS calculation results for Variant I, and Figure 19 shows the corresponding results for Variant II. In both figures, the results include values and graphical representations of the displacements and deformations of the abutment-pile system (SLS), as well as the forces and bending moments in the piles (ULS).

It can be observed that, similar to Example 1, the Q-s characteristics of piles in a group had the greatest influence on the displacements of the analysed structure and the bending moments in the piles (internal forces in the abutment body were not analysed). With regard to bending moments in the piles, it is notable that in Variant II the shapes of the bending moment diagrams were entirely different compared to those obtained in Variant I.

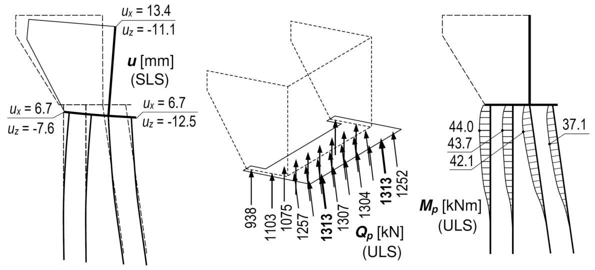

Figure 18. Bridge abutment calculation results for Variant I.

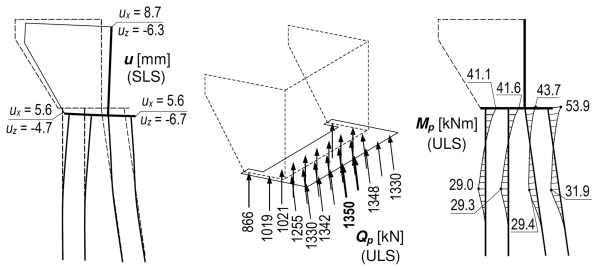

Figure 19. Bridge abutment calculation results for Variant II.

6 INTERPRETATION AND EVALUATION OF PILE LOAD TEST RESULTS

The proposed computational approach also determines a change in the approach to interpreting and evaluating the results of pile load tests. This interpretation involves generating a pile settlement curve from the test $(Q\text{-}s)_{SPLT}$ (characteristic and design, according to EC7). Next, this curve should be compared with the bilinear $(Q\text{-}s)_k$ and $(Q\text{-}s)_d$ graphs of the single pile used in the design calculations. The comparison, and therefore the pile test, will be assessed positively, if the $(Q\text{-}s)_{SPLT}$ graphs lie above the design graph, as shown in Figure 20. This indicates that the constructed piles perform better than those assumed in the design.

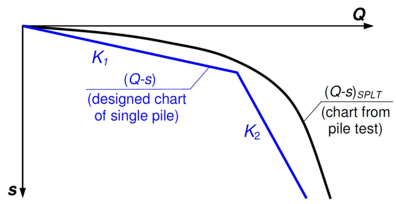

Figure 20. Interpretation and evaluation of the pile load test result (positive result).

Otherwise, the pile test result will be assessed negatively, but this will not necessarily pose a significant problem. In the case of minor deficiencies in the pile load-bearing capacity, it may be sufficient to re-analyse the pile foundation using new *Q-s* characteristics, determined from the pile load tests and, if necessary, to slightly strengthen the pile cap structure (e.g., increase the reinforcement). Otherwise, reinforcement with additional piles is recommended. Nevertheless, there is no need to determine the pile load-bearing capacity, understood as the numerical value R_c, from the load test.

7 SUMMARY AND CONCLUSIONS

The proposed approach to calculating and designing pile foundations offers an attractive alternative to current methods. It is simple, easy to use, and better represents the interaction between piles, soil, and the entire structure. Although more labor-intensive, the benefits outweigh the extra effort, especially with the support of computer applications or spreadsheets, which can reduce workload.

This method enables safer and more economical pile foundation design by treating piles and the capping structure as a unified system. Designers gain greater flexibility and confidence in their results. Examples show that reliable results at both the serviceability limit state (SLS) and ultimate limit state (ULS) require using nonlinear or bilinear pile characteristics that consider group interactions. However, for grid beams on piles spaced over $5D$ apart, pile interaction can be neglected.

A major advantage of this approach is its clear and objective interpretation of static pile load tests. Instead of determining numerical ultimate or design capacities, it compares actual pile settlement curves directly with those assumed in design, simplifying and clarifying the evaluation process.

8 REFERENCES

Bohn C., Lopes des Santos A., Frank R. 2016. Development of axial pile load transfer curves based on instrumented load tests. J. Geotech. Geoenviron. Eng. DOI: 10.1061/(ASCE)GT. 1943-5606.0001579.

Chow Y.K. 1986. Analysis of vertically loaded pile groups. Int. Journal for Num. and Anal. Methods in Geomechanics, Vol. 10, pp. 59-72.

De Cock F., Legrand C., Huybrechts N. 2003. Overview of design methods of axially loaded piles in Europe - Report of ERTC3-Piles, ISSMGE Subcommittee. Proc. XIII ECSMGE, Prague, 25-28 August, Vol. 3, pp. 663-715.

Dembicki E., Cudny M., Krasiński A., Załęski K. 2013. Pylon foundation of a cable stayed bridge at the motorway ring road of Wrocław. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris.

European Committee for Standardization, 2004; 2007. EN:1997-1 - Eurocode 7: Geotechnical design – Part 1: General rules; Part 2: Ground investigation and testing.

Fellenius, B.H. 2018. Development of axial pile load transfer curves based on instrumented load tests. Discussion, ASCE J. of Geotechnical and Geoenvironmental Engineering, 44(2) 4 p. doi:10.1061/(ASCE)GT.1943-5606.0001867.

Gwizdała K. 1996. The analysis of piles settlements employing load-transfer function. (In Polish). Technical University of Gdansk, Zesz. Nauk. PG Nr 532.

Gwizdała K., Dyka I. 2002. Estimation of settlements of piles in group. Proceedings of the 9th Conference on Piling and Deep Foundations, Nice, 3/4/5 June.

Gwizdała K., Krasiński A. 2016. Report of Eurocode 7 application for pile foundation design in Poland. Proc. of ISSMGE - ETC 3 Int. Symp. on Design of Piles in Europe. Leuven, Belgium.

Hemsley J.A. 2000. Piled raft foundation projects in Germany. Design applications of raft Foundations. Published by Thomas Telford Ltd, London.

Krasiński A. 2012. Proposal for calculating the bearing capacity of screw displacement piles in non-cohesive soils besed on CPT results. Studia Geotechnica et Mechanica, Vol. 34 (4), pp. 41-51, DOI: https://doi.org/10.2478/sgm041204.

Krasiński A. 2014. Numerical simulation of screw displacement pile interaction with non-cohesive soil. Arch. of Civil and Mech. Eng., 14(1):122–133, http://dx.doi.org/10.1016/j.acme.2013.05.010.

Krasiński A. 2022. Propozycja procedury obliczania i projektowania fundamentów palowych. (Proposed procedure for calculating and designing pile foundations) (In Polish). Materiały XXXVI Ogólnopolskich Warsztatów Pracy Projektanta Konstrukcji, Wisła, Poland.

Poulos H.G., Davies E.H. 1980. Pile foundation analysis and design. John Willey and Sons, New York.

Poulos H.G. 1988. Modified Calculation of pile-group settlement interaction. Journal of the Geotech. Eng. Division, ASCE, USA, Vol. 114. GT6, June, p. 697-706.

Randolph M.F., Wroth C.P. 1979. An analysis of the vertical deformation of pile groups. Geotechnique, Vol. 29, 4, pp. 423-439.