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STUDY CONCERNINGTHE BEHAVIOR OF FOUNDATION ELEMENTS IN PUNCHED HOLES

Mirea Monica [1]

Abstract: This study analyses, through MEF, the behavior of 10 foundation systems under different loading levels. These foundation systems were realized considering 4 specially shaped precast elements successively placed in dug holes, in punched holes and in bulb punched holes. The results show a very good behavior of the analyzed element compared to the other elements taken into consideration. The fact is due to the better cooperation of the proposed element with the foundation ground, fact that results in a higher bearing capacity.

Keywords: bearing capacity, foundation ground, punching holes, settling.

1. GENERAL REMARKS

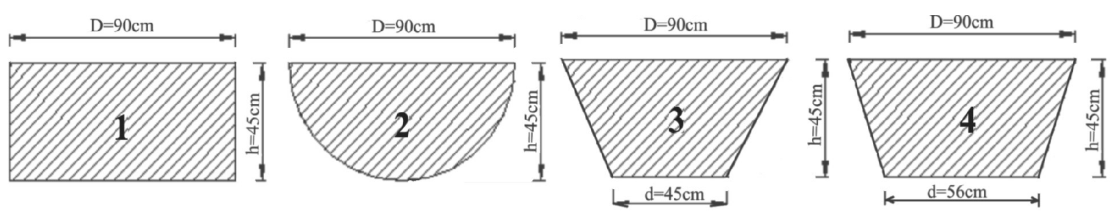
The foundations realized in punched holes, through their shape and technology, represent both a foundation solution per se, and a solution for improving the soil around the foundations, enhancing their bearing capacity.

The punched foundations present, as compared to the classical foundation solutions, the advantages connected to the diminution of the foundation depth, of the foundation size and of transmitting higher loadings to the foundation ground.

This research used a new foundation semi-sphere element, whose behavior under loadings will be compared to that of other foundation elements (truncated cone in shape and having circular plate).

In order to enhance the bearing capacity of the foundation ground, we tried to enlarge the compacted area at the bottom of the foundation by realizing a bulb (granular material with higher mechanic resistances or hard concrete) in the lower part of the foundation.

The bearing capacity of the realized foundation will depend on the sizes of the packed area, the size of the bulb (realized at the basis of the foundation), as well as the physical-mechanical characteristics of the soil within the packed area. The punching method can be applied both on normal and week foundation soils.



a) b) c) d)

Fig. 1. Types of specially shaped precast elements

2. MODELLING OF THE RESEARCHED FOUNDATION SYSTEMS

The study analyzed the behavior of 10 foundation systems under different loading levels. These foundation systems were obtained considering 4 specially shaped precast elements (figure 1) successively placed in dug holes, punched holes and bulb punched holes. The dug holes consist in digging the material from the inside of the holes. The punched holes consist of realizing the hole by packing the soil in depth and sidewise with a hammer having the shape of the foundation element. The bulb punched holes consist of first realizing a punched hole which will subsequently continue with the realization of a granular or hard concrete bulb at its bottom. The modeling of the chosen foundation systems was realized with the help of the CESAR LCPC [1] program. The specially shaped precast elements chosen for research are the following:

- precast element 1 (classical foundation) shaped as a circular plate (fig.1.a), having the diameter d = 0,90 m, height h = 0,45 m and the volume V = 0,2861 m^3;
- precast element 2 having a semi-sphere shape (fig.1.b), the diameter d = 0,90 m and the volume V = 0,19085 m^3;

1 “Politehnica“ University of Tmişoara, Faculty of Civil Engineering, Department CCTFC, 1A Ioan Curea St. 300223, Timişoara, Romania, monica.mirea@ct.upt.ro

- precast element 3 truncated cone in shape (fig.1.c), in sizes D = 0,90 m, d = 0,45 m, h = 0,45 m and V = 0,16691 m^3;

- precast element 4 truncated cone in shape (fig.1.d), in sizes D = 0,90 m, d = 0,56 m, h = 0,45 m and V = 0,189577 m^3 [2].

In determining the size of the foundation elements the aim was to have the same diameter D = 0,90 m and the same height h = 0,45 m. The truncated cone precast element with d = 0,56 m was chosen because its volume is close to the volume of the semi-sphere element.

The behavior model of the foundation-foundation ground ensemble was realized taking into account axially symmetric structures, the calculation being realized in the elastic-plastic field. The ground was modeled on a 6 m depth (which represents over 13 times the element height) under the foundation foot, and sidewise a 3 m radius was considered (over 6 times the element height).

Four types of materials with different physical-mechanical characteristics and behavior laws have been defined for modeling the foundation systems.

For the precast elements, the concrete criterion was used as behavior law. For the foundation ground (clay silt) and for the packed area in the foundations realized in punched holes, the Mohr-Coulomb law was used as a behavior law. For the material in the bulb (hard concrete) in the foundations realized in bulb punched holes, the concrete criterion was used as a behavior law.

The sizes of the packed area, in the foundations realized in punched holes without bulb, were determined according to the guide C230-89 [3] as follows:

- height of compacted area $h_c = 1{,}5 \cdot b_m$

- radius of compacted area $r_c = b_m$ where $b_m = (D+d)/2$ for the truncated cone shaped element and $b_m = 0{,}78$ m for the semi-sphere shaped element.

In the case of foundations realized in punched holes with bulb, the sizes of the bulb and the sizes of the packed area were determined according to the same guide, as follows:

- bulb height $h_b = 0{,}9 \cdot b_m$, bulb radius $r_b = 0{,}8 \cdot b_m$, height of the packed area $h_c = 2b_m - h_b$ and radius of the packed area $r_c = 1{,}5 \cdot b_m$.

The loading was applied on 5 loading levels from 1 daN/cm^2 to 5 daN/cm^2 with a step of 1 daN/cm^2.

The calculation of the stresses and the deformations was realized with the help of the CESAR-LCPC calculation program, and the PEGGY-2D post-processor was used in visualizing the results.

As far as the calculation results, the PEGGY post processor offers a detailed analysis of the stress condition, deformations and movements, the possibility of following the distribution of strains on the ground as well as the plasticized areas. In order to compare the loading-settling diagrams for the researched variants, the results obtained with CESAR-LCPC were transferred sand superposed in EXCEL.

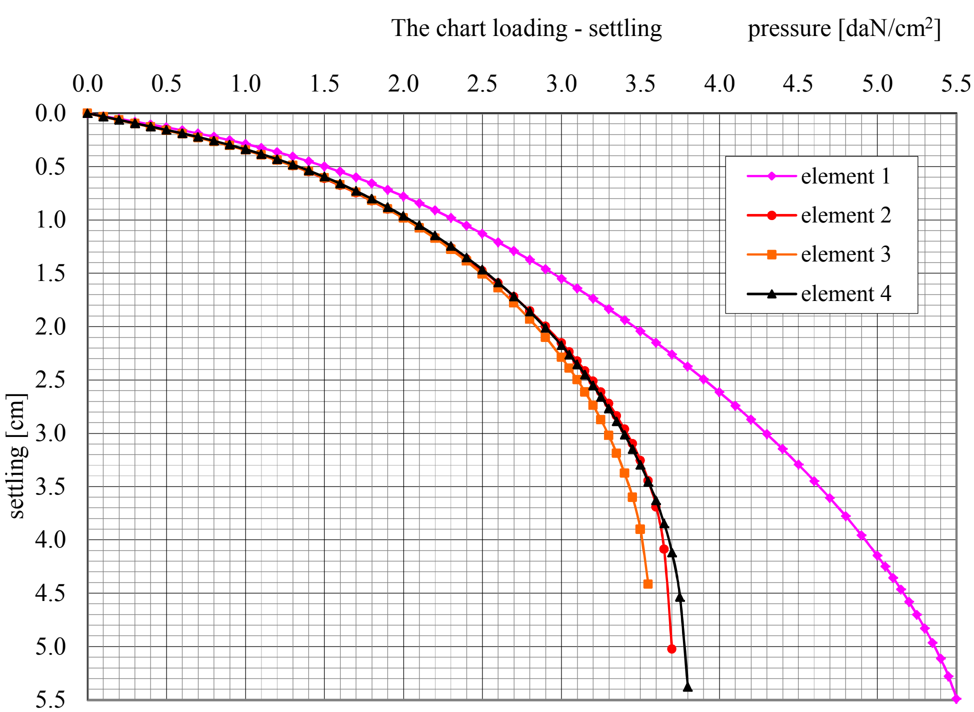


Fig. 2. Loading-settling charts for the elements 1, 2, 3, 4 placed in dug holes

3. ANALYSIS OF RESEARCHED FOUNDATION SYSTEMS BEHAVIOR UNDER LOADINGS

In order to analyze the behavior under loading of the researched foundation systems the loading-settling diagrams for imposed settlings of 2,5 cm and 4 are compared.

Stage I consists in placing the precast elements (1…4) in dug holes and loading them in levels from 1 daN/cm^2 to 5 daN/cm^2.

The results obtained are shown in figure 1. It can be noted that for a 2,5 cm settling the best bearing capacity is provided by element 1 with p = 3,9 daN/cm^2, followed by the specially shaped elements 2 and 4 for which p ≈ 3,2 daN/cm^2. Element 3 presents p ≈ 3,1 daN/cm^2.

For the 4 cm settling the same behavior is observed.

In stage II, which consists in introducing element 1 in a dug hole and elements 2, 3, 4 in punched holes, we notice an improvement of the bearing capacity of the specially shaped elements.

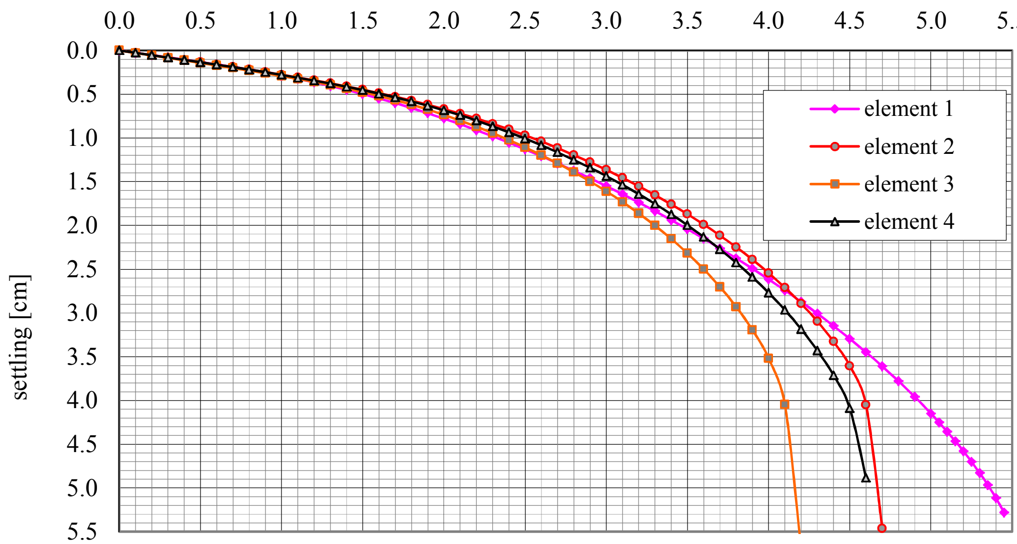


Fig. 3. Loading-settling charts for the precast elements:
1 in dug holes and 2, 3, 4 in punched holes without bulb

In stage III, when element 1 is realized in a dug hole and elements 2, 3, 4 are realized in punched holes with gravel bulb, it is noticed that all specially shaped elements have a higher bearing capacity than element 1 (fig. 1 and 4). Also, for the first time, the advantages of element 2, as compared to elements 3 and 4, are underlined, showing a bearing capacity 10 - 25 % times higher than that of element 1, for the 2,5 cm settling. For the 4 cm settling the difference is even more obvious.

The centralized results are presented in table 1.

Table 1. Centralizing table for stage III

Settling [cm]	Element 1 daN/cm^2	Element 2		Element 3		Element 4	
		daN/cm^2	%	daN/cm^2	%	daN/cm^2	%
s = 2,5 cm	3,9	6,65	170	5,7	146%	6,25	160
s = 4 cm	4,9	8,75^2	178	7,25	148%	8,05	164

Figure 4 presents the loading-settling charts for the prefabricated elements 3 and 4 in dug hole, in punched hole without bulb and in punched hole with bulb.

The comparison of the two truncated cone elements shows that the element with a larger average diameter presents a better behavior.

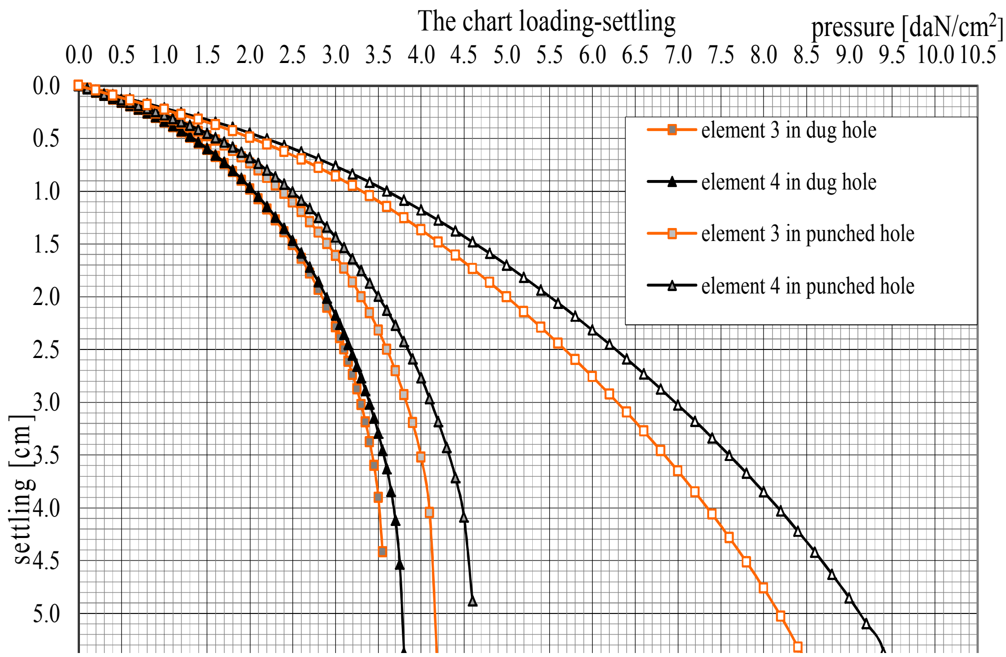


Fig. 4. Loading-settling charts for the precast elements 3 and 4 in dug hole, in punched hole without bulb and in bulb punched hole

4. CONCLUSIONS

The results obtained show a very good behavior of the element in semi-sphere shape (2) as compared to the truncated cone elements (3, 4) fact due to the more advantageous distribution of the stress in the foundation ground.

It is worth mentioning that the volume of the element 1 is 1,5 times larger than the volume of element 2, 1,71 times larger than element 3, 1,5 times larger than element 4; therefore the bearing capacity per volume unit is smaller in element 1.

This is due to the better cooperation of the specially shaped foundation elements with the foundation ground. Element 2 finally leads to the best bearing capacity.

This solution for the realization of foundation holes contributes to the reduction of the digging volume and of the materials used in foundations, the decrease of the quantity of materials needing transportation (soil, concrete, steel-concrete, wood for shuttering, etc.) as well as to shortening the execution period. All these reflect favorably upon the environment, the costs of the investment being finally lower than in the case of other known solutions. [4]

The hemispherical shape of the foundation and of the punching element respectively causes a more vertical and horizontal extension of the packed area, which impacts favorably upon the bearing capacity of the foundations realized in punched holes with hemispherical element as compared to the punching elements used up to the present. [5]

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