Bearing Capacity of Piles with the Spot Footing

La Capacité de Charge des Pieux avec le Fondement

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SYNOPSIS The work contains the results of field and model investigations concerning the carrying capacity of piles working with cooperation with the spot footing. The model investigations were performed in sands having the relative density equal to I_D = 0,4 - 0,8. By means of electric tensometric sensors the force value taken by footing and pile was measured as well as the axial force distribution along the pile. Additionally the settlement of pile and footing were measured separately as well as the settlement of whole system under load. The model experiments proved that the carrying capacity of pile - footing foundation is greater than the sum of carrying capacities of pile and footing when taken separately. The field investigations were performed with Wolfsholz and Frank type piles having the 40-42 cm diameter and 5,0-14 m length. The experiments were performed on silty loams and proved that the carrying capacity of piles cooperating with spot footing was 30-60 percent greater than carrying capacity of piles working alone.

INTRODUCTION

When computing the carrying capacity of pile foundation its commonly assumed that the whole building weight is transferred to ground only by means of piles and that the foundation slab /basement slab/ or basement footing plays only constructional role, coupling the pile heads together and transferring to them the building loads.

Such an assumption is correct for such geological conditions where the upper ground bed are weak soils /muds, peats, cohesive soils in plastic or liquid state/ and the pile transfers the load to carrying strata mainly by its foundation.

Anyway, in engineering practice, situation may happen when it is necessary to set the building on piles even in case when the upper ground beds are soils which may transfer loadings but their carrying capacity is less than actual unit bearing pressure.

Such situations may occur when lying the basements of industrial objects where the great loadings are to be suspected. Cases like mentioned above may justify the opinion that at such conditions the certain part of loading shall be transferred by means of pile plate directly to ground and that the carrying capacity of foundation will be greater than computed, when taking into account only the carrying capacities of piles.

Up to date there are no sufficient data concerning the percent contribution of piles and piles plate in carrying capacity of whole foundation.

Empirical investigations concerning this subject are not numerous ie: J.Pałka /1964/; J.Pałka and J.Naborczyk /1968/; W.Knabe /1971/ and J.A.Hooper /1973/.

MODEL INVESTIGATIONS

In attempt to investigate the character of foundation behaviour and in attempt to determine the percent contribution of pile plate to carrying capacity of foundation the several model and field experiments were performed by authors of a present article.

Within the scope of model investigations the pile - footing system lying on uniform sandy ground with humidity index w_n = 0,13% and with different density index ranging from I_D = 0,4 to I_D = 0,8, was experimentally loaded. The sand was placed within container which had the shape of rectangular box with the following dimensions: 1,16 × 0,96 × 1,05. The container was build over the steel skeleton and its walls were made of organic glass. The pile models were 40 - 85 cm long and their diameter was equal to 3 cm. The models of footings were of a circular shape and had diameter equal to 10 and 15 cm. The load was applied by means of tensiometric sleeve in attempt to measure the value of force transferred to pile and to footing. During the experiments the following values were measured by means of tensiometric sensing devices:

- pile settlement value
- footing settlement value
- value of settlement of the whole system under load
- distribution of axial force in pile

The number of performed series of measurements amounts to 30 and the results obtained are shown on Figure No. 1.
The authors, as well, performed the series of experiments in situation where the certain clearance was allowed between the pile and the loading surface of footing.
In this case the loading was initially transferred only through the footing and afterward, when the settlement value topped over 5 mm, the pile was incorporated into cooperation with footing.

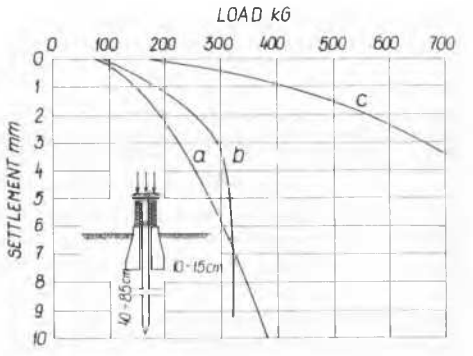

Fig. 1. Relation between the settlement value and load value

a - pile 49,3 cm long and having the diameter equal to 3 cm

b - footing with 15 cm diameter

c - pile - footing system

The pile-footing foundations usually had a greater carrying capacities with simultaneous transfer of loads on pile and on footing.

The tensiometric measurements of axial force distribution in pile which cooperates with footing proved that, when the load is simultaneously transferred to pile and footing, then, initially, the nearly whole load is taken by pile.
The performed model experiments proved that the carrying capacity of pile-footing foundation is greater than the sum of carrying capacities of pile and footing taken separately.
This difference increases with the increase of pile-footing foundation settlement value. Similar results for piles working together were obtained by W.Knabe /1971/. This results were also achieved in model experiments.

FIELD INVESTIGATIONS

Field investigations were performed with piles of Wolfsholz and Frank type. In case of Wolfsholz piles the ground constituted the cohesive soils such as loams and silty loams having the following parameters:

- specific density $\gamma = 2{,}1$ G/cm^3
- angle of internal friction $\phi = 14\text{-}18^o$
- cohesion $c = 0{,}2 - 0{,}3$ kG/cm^2
- liquidity index $I_L = 0{,}19$

The piles having the following dimensions:

- diameter - 40 cm
  length - 5 m

were preliminary loaded, provided that piles are equipped with foundation footings having the surface 1 m^2 for each pile. Performed investigations proved that the piles equipped with footings have 30 - 60% greater carrying capacity than separate piles which worked in the same geological conditions.

The curve of pile settlement for one on measurement series is shown on Figure 2. Conclusions of mentioned above investigations were practically employed to solve the problem of setting the six eleven floors apartment buildings. The ground substratum of these buildings were made of silts and silty loams having the following parameters:

- liquidity index $I_L = 0{,}28 - 0{,}33$
- unit weight $\gamma = 2{,}0$ G/cm^3
- angle of inner friction $\phi = 14^o$
- cohesion $c = 0{,}13$ kG/cm^2

8 to 11 meters below the level of foundation the ground parameters are much worst and have the following values:

$I_L = 0{,}42$ $\phi = 12^o$ $c = 0{,}1$ kG/cm^2

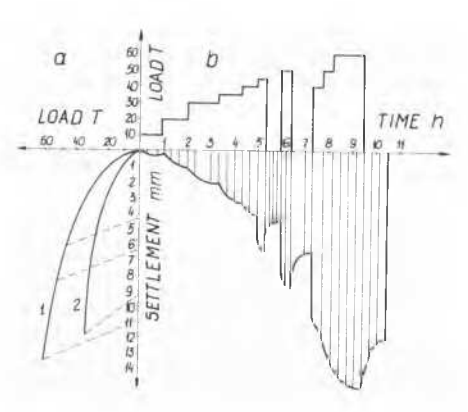

Fig. 2. Results of applying the preliminary load on Wolfsholz type piles having 5 m length and 40 cm diameter

a - curve showing the relation between settlement and load
1 - pile with footing
2 - separate pile

b - curve showing changes of settlement value with time, for pile with footing

Taking into account that the buildings have to be made of prefabricated elements /multiblock prefabricated construction/ which is sensitive to nonuniform settlement, the foundation was design to be made of Frank type piles with following dimensions:

length - 14,0 m
diameter - 42 cm

Experimental loading of 8 piles proved that their carrying capacity is equal to 50-60 ton. The same piles equipped with footing having 1,2 × 1,2 m dimension, experienced 30 - 50 percent higher carrying capacity at the same other conditions /Fig. 3/.

Basing on results scheduled above it was decided that the amount of piles needed,

should be established with assumption that the piles transfer 60 percent of the whole load and that the rest /40 percent/ is transferred by pile plate.
During the seven years of exploitation the buildings in question don't bear any evidence of construction damage and their settlements are uniform and don't top over 12 mm.

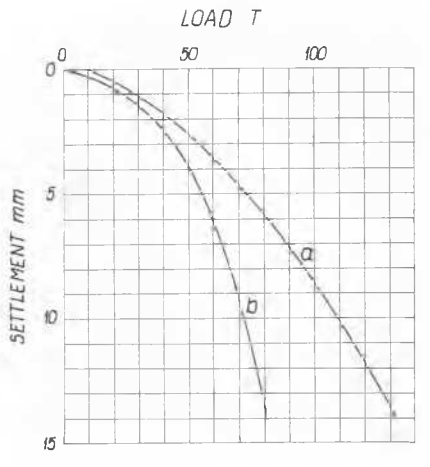

Fig. 3. Results of experimental loading of the Frank type piles /length 14,0 m, diameter 42 cm/

a - pile with footing 1,2 × 1,2 m
b - pile without footing

CONCLUSIONS

The performed investigations proved that in case of setting the buildings on piles in some geological conditions, the foundation load is transferred to ground substratum not only by means of piles but also by foundation plate or pile footing.
Taking this into account during designing the pile foundation may brought about some economical profits.
The model investigations of pile - footing foundation behaviour in sandy ground proved that the carrying capacity of the whole system is greater than the sum of carrying capacities of pile and footing when taken separately.
Field investigations of Frank and Wolfsholz type piles working with cooperation with spot footing proved that their carrying capacity is 30-60 percent greater than carrying capacity of these piles when not equipped with footings.
The experience gained during designing of 6 mentioned apartment buildings proved that the assumption that 60 percent of load is taken by piles and the rest 40 percent is taken by piles plate is fully justified and completely safe in case of cohesive soils having the relative consistency I_L = 0,20 - 0,30.

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