Model tests of bearing capacity of homogeneous soil limited by rigid layer

Essais sur modèles de la capacité portante d'une couche d'un sol homogène limitée par une assise rigide

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SUMMARY: This paper presents the results of model tests of bearing capacity of homogeneous, noncohesive soil limited by rigid layer with regard to two-dimensional aspect of this phenomenon. In the paper some examples of influence of different relative position of rigid base for bearing capacity and distribution of displacements in deformable subsoil are also presented.

RESUME: Dans cet article on present les rèsultats des essais sur modèle superficielle reposant sur une couche d'un sol homogène d'epaisseur limitée. Les examples d'influence de la position relative une assise rigide sur la capacité portante et la distribution des deplacements en couche déformable sont fournis aussi.

1 INTRODUCTION

The problem of determination of bearing capacity as a reaction of a subsoil on loading by spread foundation was investigated by a lot of researchers. In spite of that, a general explicit method for exact general solution applicable in most of the conditions encountered in engineering practice does not exist till now. Therefore, the approximate and simplified solutions are widely adopted. Such solutions can be successfully applied for some individual cases of a design of engineering constructions but the scope of its applications is rather narrow.

In the individual problems the knowledge of actual values, distribution and changes with regard to bearing capacity of thin soil layer resting on rigid base strongly contributes to economic and safe design. Therefore, the problem of bearing capacity still focuses the attention of many researchers. The objective of this paper is to present the results of model tests of bearing capacity developing in non-cohesive soil resting on the rigid base in 2D-strain state. The experimental programme was based on the analysis of state of the art of the problem together with numerical considerations and incorporation of general trends in design of model tests.

2 EXPERIMENTAL SET

In the tests both constructional solutions of qualitative analysis as well as measurement technique applied in quantitative experiments have been adopted. In the tests described below special technique of measurement of stress components on the contact surface between deformable soil layer and rigid base has been employed. In the technique which was elaborated in the Geotechnical Laboratory of

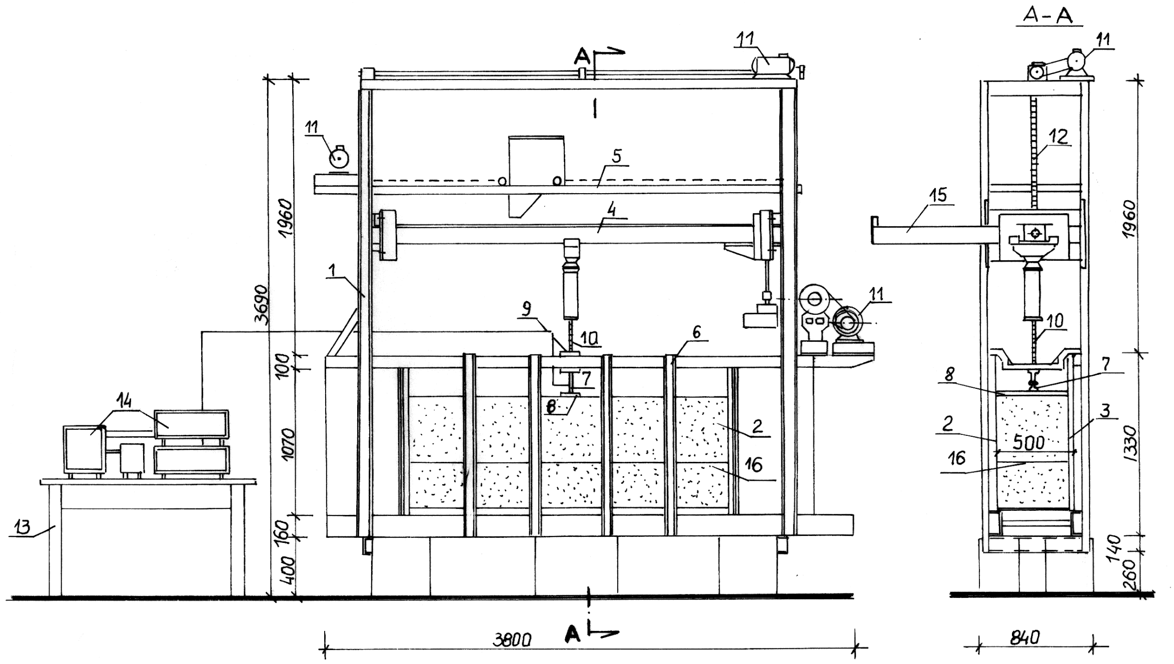

Figure 1. Scheme of experimental set.
1-main frame, 2-measurement box, 3-glass, 4- hoist frame, 5-sand pluviation, 6-glass reinforcements, 7-dynamometer, 8-model, 9-additional frame, 10-hoist screw, 11-engine, 12-worm gear, 13-table, 14-measurement set, 15-loading frame' s bracket, 16-rigid base

Gdansk special gauges for measurement of tangent and normal stress components have been used. The scheme of experimental set is shown on Figure 1. In all tests two steel models of spread foundation were used with following dimensions : width 10/20cm, height 8cm and length 50cm; all axially loaded. The stress gauges were built in rigid base made on aluminium P13 alloy with smooth surface. All details referring to methods and obtained results of measured stress components can be found in Srokosz (1998), Bartoszewicz et al. (1999), Dembicki et al. (1999,2000).

3 MODEL TESTS PROGRAM

In the tests fine “Lubiatowo” sand has been used with the parameters shown in Table 1.

Table 1. Parameters of "Lubiatowo" fine sand.

coefficient of uniformity C_U	1.26
Particle size D_{10}	0.17 mm
Particle size D_{60}	0.21 mm
Specific gravity G_S	2.6 Mg/m^3
minimum bulk density of dry soil ρ_{dmin}	1.423 Mg/m^3
maximum bulk density of dry soil ρ_{dmax}	1.717 Mg/m^3
average bulk density of dry soil ρ_d	1.579 Mg/m^3
angle of internal friction Φ	28.2°
angle of dilatation Ψ	9.8°
average moisture content w_n	0.1 %
Apparent cohesion c	2.23 kPa
Poisson’s ratio ν	0.3

Table 2. Tests program. Models axially loaded.

Symbol of experiment	Height of soil layer	Type of foundation			
		shallow		deep	
		Width of model			
		B=10cm	B=20cm	B=10cm	B=20cm
	2,5B	-	E1	-	E5
	2B	AC	C1,E2	AC1	C2
	1,5B	CA	D1,E3	CA1	D2
	1B	BC	A1,A11,E4	BC1	A2
	0,5B	-	AB	-	AB1

Tests program is presented in Table 2. For "deep" case of foundation the relative depth of model was equal 0,25B. In all performed experiments contact surface between foundation models and subsoil was smooth.

4 SOME EXAMPLES OF OBTAINED RESULTS

Figure 2 presents an example of obtained results for a shallow model with width B=20 cm. Analysis of relation between the values of reaction of subsoil and settlement of foundation changing in time has made possible to separate four phases of soil behaviour:

- phase I - rigid-linear elastic, for model settlements from 0,0 to 0,1mm,
- phase II - nonlinear elastic, for settlements from 0,1 to 0,6 mm,
- phase III - elastic-plastic, for settlements from 0,6 to about 7mm,
- phase IV - purely plastic, after exceeding maximum bearing capacity of subsoil, for settlements beyond 7 mm.

Complete analysed set of experimental results for shallow and “deep” foundation are shown in Figures 3 and 4 respectively. As it can be noticed, influence of rigid base for bearing capacity is neglected for relative depth H higher then 1,0B for shallow case and 1,5B for “deep” case of foundation.

Furthermore displacement fields in subsoil during experiments have been observed using special marks placed in deformable layer, behind the glass window in experimental box. Analysis of displacements of grains has been possible thanks to photogrametric picture recording. An example of net of marks is shown in Figure 5.

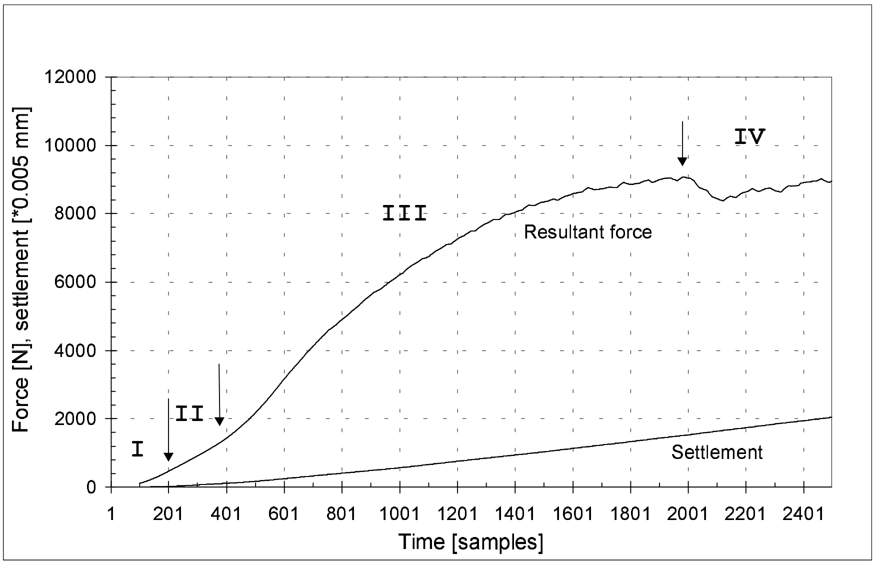

Figure 2. Values of resultant force and settlement changing in time. Behaviour phases of set : model-subsoil. Model test E1.

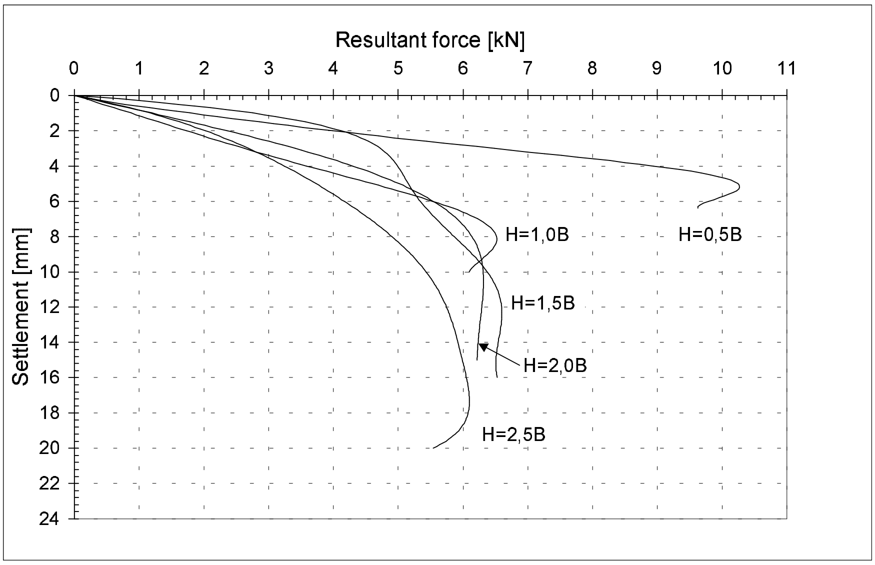

Figure 3. Relation between resultant force and settlement for different relative position of rigid base. Model tests : E1, E2, E3, E4, AB.

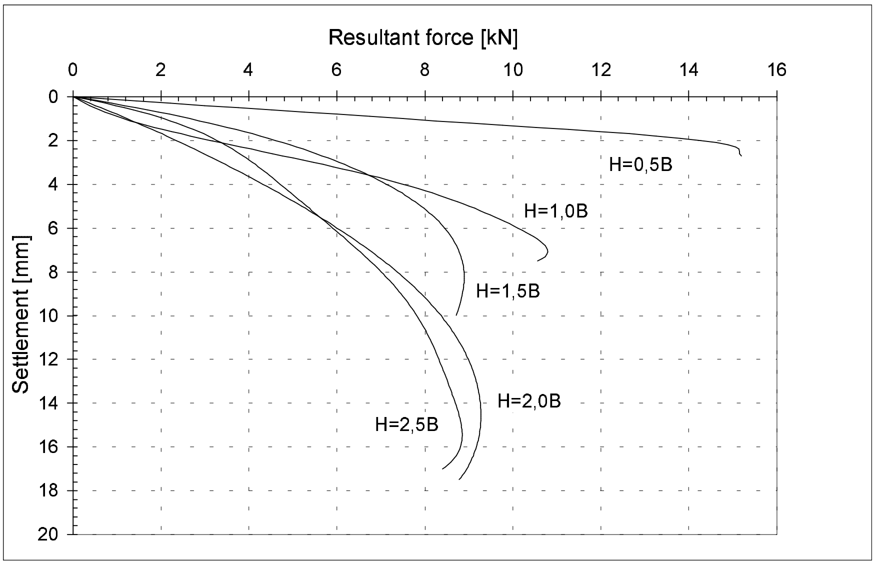

Figure 4. Relation between resultant force and settlement for different relative position of rigid base. Model tests : A2, C2, D2, E5, AB1.

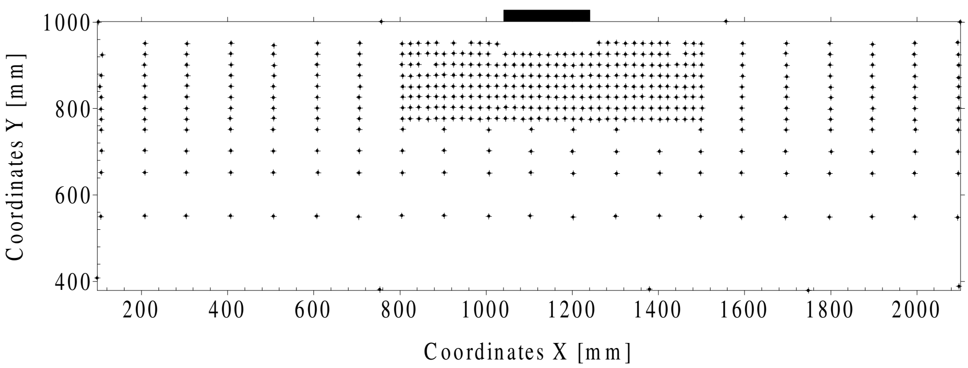

Figure 5. Net of marks. Model test: E1.

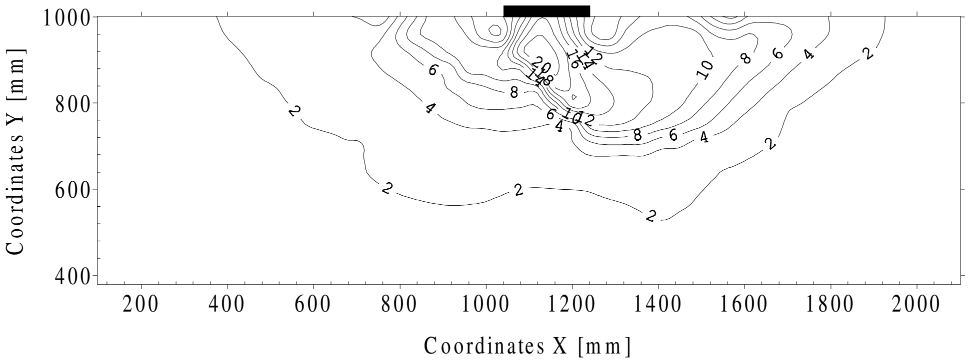

Figure 6. Displacement field obtained in model tests E1.

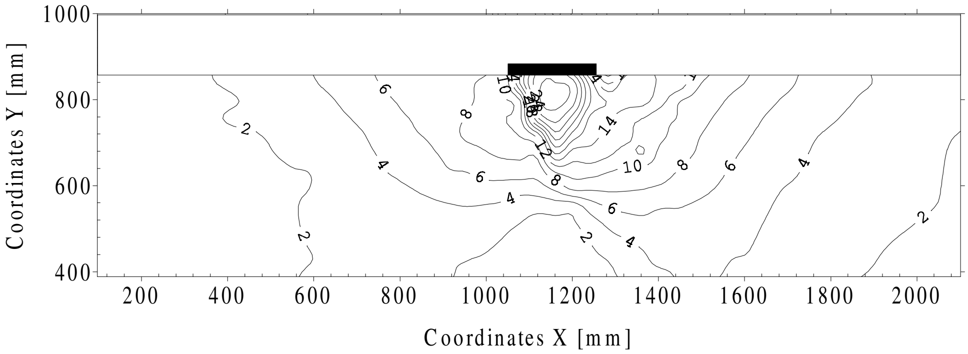

Figure 7. Displacement field obtained in model tests E2.

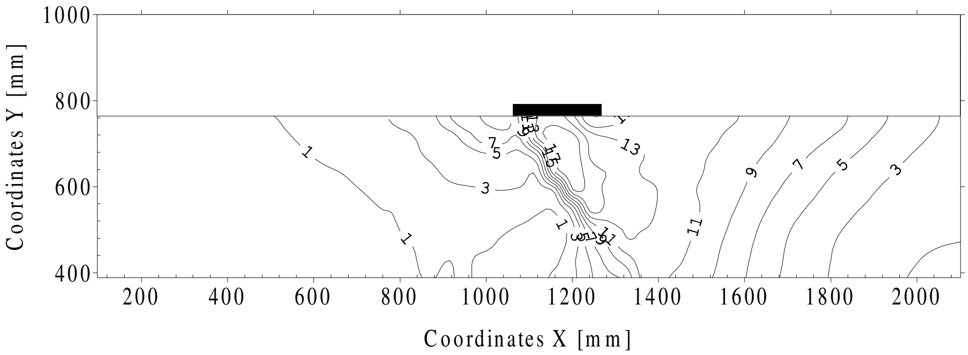

Figure 8. Displacement field obtained in model tests E3.

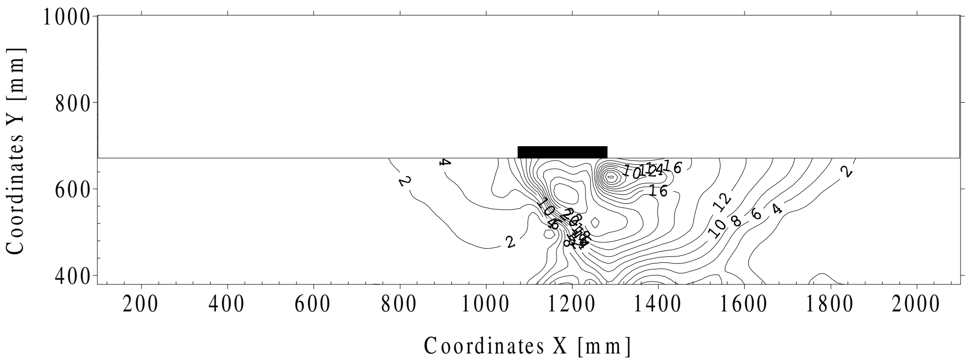

Figure 9. Displacement field obtained in model tests E4.

Figures 6-9 show examples of obtained displacement fields for different relative positions of rigid base after 2D analysis of photogrametically taken pictures. It can be noticed, that strains of subsoil are not symmetric, especially for small heights of deformable layer: 1,5B and 1,0B. This phenomenon is connected with high values of resistant force (bearing capacity) and with consequences of difficulties to keep load direction ideally in vertical axis of the model.

5 CONCLUSIONS

Presented results of partially performed analysis of huge amount of experiments, which have been realized for last 3 years, make one of several parts of main scientific project, which has been developed in Geotechnical Department of University in Olsztyn for over 10 years. Authors have been carrying out problems connected with modernization of experimental sets and measurement techniques, to lead finally evaluation of polish standards and codes (i.e. PN81/B-03020) for designing spread footings.

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