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NUMERICAL MODELING OF RAFT FOUNDATIONS

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Abstract: *This paper presents solutions based on selection of parameters and models for simple examples of raft foundations with short descriptions of the methods. Methods for calculation and design of raft foundations can be classified into three main groups: static or approximate, theoretical and numerical methods. Another way of their classification is according to the model used in presenting the soil: methods based on the Winkler hypothesis and on solid infinite space. This discussion is more focused on structural responses of raft foundation than on geotechnical aspects. This paper presents some examples on application of these methods, along with discussion of the results.*
Key words: *raft foundation, loads, numerical methods*

1. INTRODUCTION

Various theoretical and numerical procedures are developed to obtain an approximate solution for real distribution of stresses in the foundation-soil interface. An approximately actual state that is satisfactory in practice is reached by development of numerical procedures and in-depth investigation of soil deformation properties (Vesic, 2000).

2. PREVIOUS RESEARCH

2.1 Static methods

Slabs can be designed using static methods, which produce contact pressures according to the following hypotheses:

- Contact pressure develops linearly under the slab.
- Contact pressure develops dependent on areas affected by columns.

The first hypothesis is more practical for stiff slabs, while the second method is more convenient for elastic slabs. These methods are commonly referred to as static methods because no particular attention is paid to compatibility between settlement and contact pressures. These methods can be used only to determine internal forces in a foundation slab, and can not establish exchange of settlements over slab. For linear variations, contact pressures are calculated using the resultant of downward acting forces. This method can be applied to rigid slabs, such as box-shaped or slabs stiffened by depth beams.

Design by the influence method is commonly used for more elastic slabs. Contact pressures of different influence areas and internal forces in the slab are solved as if the slab is essentially a floor supported by columns and loaded by contact pressures. (Baker, 1957) proposed a simplified method (that can be considered a static method) for calculation of raft foundations on types of soil in which properties change in the horizontal direction. This method gives results approximate to the Winkler method in case of a homogeneous soil.

2.2 Methods based on Winkler's hypothesis

According to Winkler's hypothesis, contact pressure p on the foundation base is proportional to settlement w (Prskalo, 2008). Therefore the following applies:

$$p = k \cdot w \tag{1}$$

where:
k - coefficient of soil reaction (kN/m^3)
p - load (kN/m^2)
w - settlement of soil (mm)

Coefficient of soil reaction of some models is considered for two extreme cases, and these are zeroth and infinite stiffness of the foundation relative to the ground. Differences are very recognizable in the contact pressure under stiff foundations, and in the settling of very elastic foundations. The last paragraph indicates a drawback of the Winkler model because it is only the points below the foundation that settle due to the foundation load. In reality, the soil around the foundation area is settling together with the soil below the foundation, causing a curved shape of the foundation curve in the diagram for uniform loads.

3. NUMERICAL METHODS

Numerical or discrete methods, most commonly used for the design of raft foundations, are the finite difference method (FDM) and finite element method (FEM). These two methods will be examined in the following chapter. Other mostly used methods are the boundary element method, the surface element method and the finite grid method (FGM).

For simple slabs, the natural choice would be the use of plate for bending of elements supported by springs (2D) or stiff elastic elements (3D). The first model (2D) is most often used in practice, and even ground with many different layers can be observed using this method to obtain favorable results. The second model provides insight into the spatial variation of soil properties, but requires a much greater computer support.

4. EXAMPLES OF NUMERICAL MODELING

A simple raft foundation with a simple arrangement of columns is chosen for the first exercise and comparison between the following methods:

- the American Concrete Institute (ACI) method
- finite difference method (FDM)
- finite element method (FEM).

Figure 1 shows a slab (the elastic modulus of concrete E=30 GPa and Poisson's ratio ν=0.2) and its dimensions, while the soil is represented by the coefficient of soil reaction of 4 MN/m^3. The example considers only bending moments in the four axes, although the methods also give large responses, contact pressure forces and settlements. Weight of the slab is not considered, and column loads are defined as concentrated point loads. The finite difference method is applied using the software (Lopes, 2000), whose view is shown in Figure 2 and Table 1.

The plate, shown in the Figure 1, is divided into square elements of 1m area (192 elements, 825 nodes in total), mostly for compatibility with other methods. Considering the dimensions of the foundation slab and arrangement of the columns, this discretisation can be considered reasonable for practical reasons too.

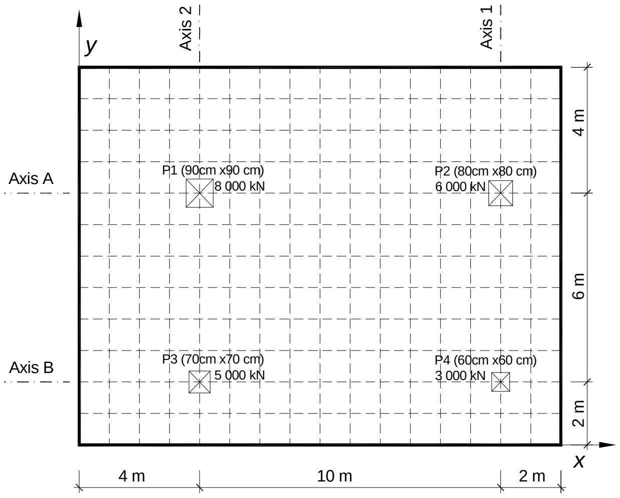

Fig.1. View of the foundation slab loaded by columns

Axis	Moment (kNm/m)	ACI	FDM	FEM (Lopes)	Tower
1	M1	268	581	735	698
	M2	-308	-116	-118	-144
	M3	1034	1704	2013	1903
2	M1	436	1023	1282	1225
	M2	-550	-108	-119	-155
	M3	1270	2069	2492	2377
A	M1	1333	2061	2480	2421
	M2	-1175	-774	-775	-661
	M3	503	1142	1453	1421
B	M1	926	1434	1684	1651
	M2	-664	-746	-746	-625
	M3	258	477	622	631

Tab. 1. Computed bending moments

Modeling of soil response according to Winkler's hypothesis was carried out using the possibility of calculation of the coefficient of soil reaction from the provided program. We examined the case of a thin plate with springs at node places. The results are shown in Table 1 and Figure 2. The range of thickness/column values is approximate to 1/8, and inclusion of deformations in the calculation did not significantly change values of bending moments.

From Figure 2, it is evident that the results obtained using the software package (Tower 6.0, 2009) almost coincide with the results obtained using the finite element method. The American Concrete Institute method gave the poorest results; however, this method is not used in practice, but is more scientific in character.

The paper presents results for the same foundation, only with loads applied in different ways. The load is not applied at points, but by distributing the force superficially or indirectly through columns. The weight of columns and slabs is not taken into account in calculation. From the calculation, we can obtain maximum and minimum moments Mx and My in the slab plane for all three cases of applying the load:

Load	minMy (kNm)	maxMy (kNm)	minMx (kNm)	maxMx (kNm)
At points	-155.01	2376.59	-662.57	2421.48
Superficially	-150.96	1721.57	-660.81	1766.16
Indirectly	-149.37	1848.53	-661.12	1896.94

Tab. 2. Moment calculated for the example from Figure 1

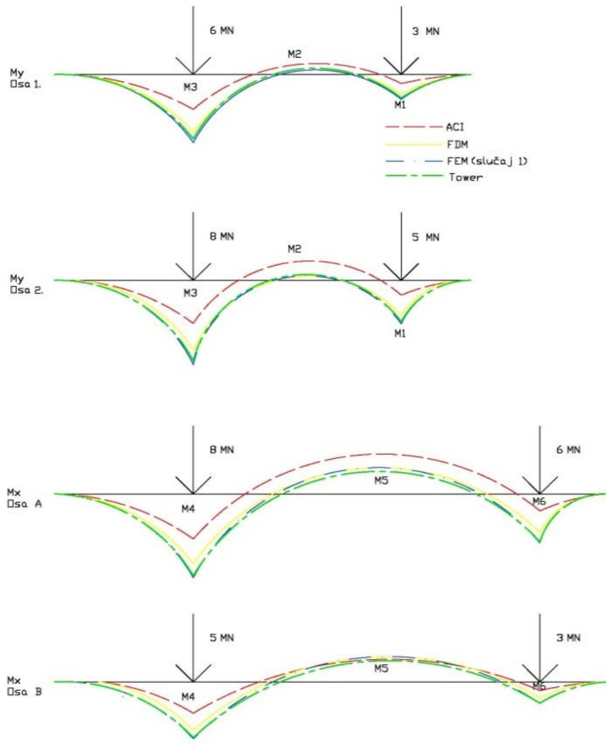

Fig. 2. Diagrams of moments for calculation values from Tab. 1

5. CONCLUSION

This paper presents solutions based on selection of parameters and models for simple examples of raft foundations. Method for calculation and design of raft foundations can be classified as numerical method based on the Winkler hypothesis. The structural response of raft foundation is by the bending moments in the four axes. The results obtained using the software package (Tower 6.0, 2009) almost coincides with the results obtained by (Lopes, 2000). But, the results for the same foundation, only with loads applied in different ways, have some variations. So, the next step is making the more complex numerical examples. They should show the connection between the changing of the coefficient of soil reaction and changing of the results. The limitations of the analyses are the FEM (software) and the deficiency of the experimental results.

6. REFERENCES

Akmadžić, V. (2009). *Model velikih pomaka u analizi plošnih i linijskih konstrukcija (Model of large displacement in analysis of surface and beam structures)*, Dissertation, Faculty of Civil Engineering University of Mostar, Mostar, B&H

Baker, A. L. L. (1957). *Raft foundation*, Concrete Publications Ltd, London, 3rd edition

Lopes, F. R. (2000). *Design of raft foundations on Winkler springs,* Design applications of raft foundations Thomas Telford Publishing, J.A. Hemsley ISBN: 0 7277 2765 6 London

Prskalo, M. (2008). *Geomehaničke odlike blidinjske sinklinale u funkciji geološkog nastanka prostora*, Dissertation, pg.56, Faculty of Civil Engineering, University of Mostar, ISBN 978-9958-9170-5-9, Mostar

Verić, F. (2000). *Savitljive temeljne konstrukcije*, Authorized lectures, Faculty of Civil Engineering, University of Zagreb, Institute for Geotechnics

*** (2009) Tower 3D Model Builder 6.0, Software, *Radimpex*, Belgrade