IOP Conf. Series: Materials Science and Engineering **365** (2018) 042038 doi:10.1088/1757-899X/365/4/042038

On the influence of modeling the increase of loads from the building frame in the analysis of stress-strain state of the of the foundation base

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Abstract. Design of bases and foundations is a complex task dependent on many different factors. Currently gained particular importance to the problem of the influence on the change of stress-strain state of the base of the foundation, increasing the load in the process of construction of buildings or structures. In this work, we performed a series of numerical experiments and the analysis of stress-strain state of the foundation soil, depending on the stress distribution at the base of the foundation. The basis set of single-layer elastic half-space with a limited depth of compressible strata. The calculations were performed using the PLAXIS 3D software package. The obtained data allowed to evaluate the selected parameters and note some features of the "base-foundation" system. The results of the series of calculations performed are analyzed by identifying the features in the distribution and the values of the parameters, depending on the characteristic features of the calculated cases, and are expressed by the following: the difference between phased and "instant" downloads, the main parameters influenced by the experiment, the influence of the construction modeling method on the magnitude and localization of the extremums of the functions of the parameters considered. As a result of the study, conclusions were drawn about the effect of the loading method on the stress-strain state of the base and recommendations were given on its modeling.

1. Introduction

For many years, the main principle of calculation and design is the accounting of joint work of bases and structures. At present, in construction practice, new technologies for the construction of buildings, calculation methods and normative documents are emerging. Numerical methods for predicting the change in the stress-strain state provide an opportunity to explain the effects of interaction between the base and the structure.

A large number of experimental and theoretical studies have been performed on the interaction of the base and the structure [1-12]. Since the existing calculation methods do not provide an opportunity to fully take into account the interaction in the "base-foundation-structure" system, research on this topic continues at present, together with the improvement of existing methods, the accumulation of experimental data and theoretical work.

The purpose of this work is to perform numerical studies of the stress-strain state of the soil massif with increasing loads during the construction process.

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The most reliable way of forecasting the change in the stress-strain state of the base of the structure under consideration, allowing to take into account the greatest number of factors affecting it (mechanical properties of the soil, geometric and rigid parameters of the foundations, complex interaction of the base soil with the foundation, etc.) is mathematical modeling by the finite element method in three-dimensional setting with the help of special geotechnical software packages.

2. Methods

To create a geomechanical model, the PLAXIS 3D software complex was chosen, which allows performing calculations in the spatial setting by the finite element method, which provides more reliable results for the problem in question in comparison with a flat setting.

The object under study is a monolithic building with a full frame, which consists of three sections 37.0 × 33.0 m on 22 above-ground floors and 3 underground (see figure 1 and 2). The pit is made in natural slopes 11.0 m deep. Such a structural layout of building is widely used in modern construction practice, especially in dense urban development.

The base set of single-layer elastic half-space with a limited depth of compressible strata. It is represented by clay-sand turgid characterized by the following values of the parameters:

- the total thickness of the base is 24.0 m
- thickness of active zone is 18.0 m
- unit weight of soil γ_{unsat} = 19.1 kN/m^3, γ_{sat} = 19.3 kN/m^3
- angle of internal friction φ = 22°
- intercept cohesion c = 28 kPa
- Poisson ratio ν = 0.35
- modulus of deformation E = 22.0 MPa

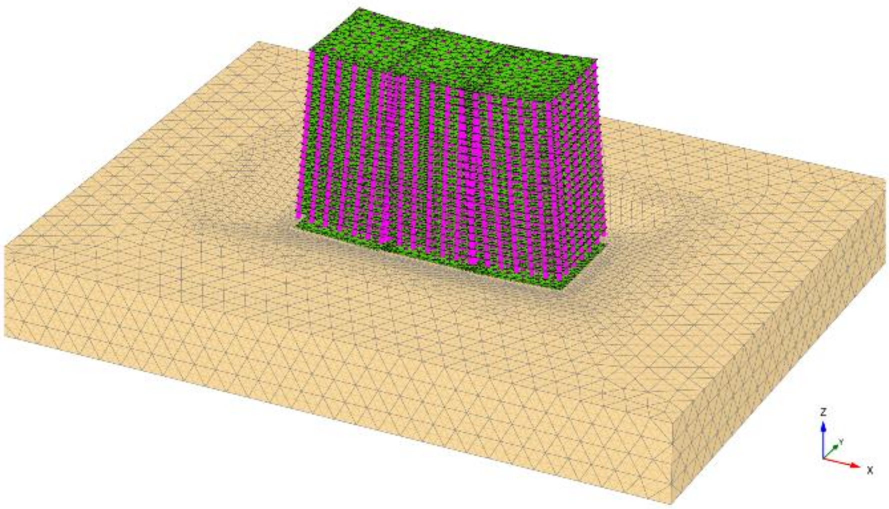

Figure 1. Deformed scheme on an enlarged scale

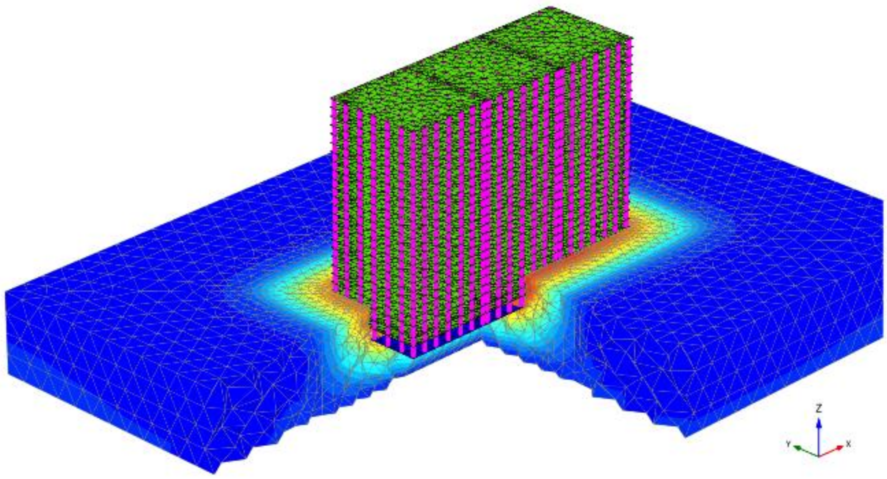

Figure 2. The design diagram of a building with fields of vertical displacements of the base

For the calculations, was chosen as elastic perfectly plastic model with a fluidity condition of Coulomb-Mohr, as the parameters required for the job are the most studied geotechnical practice, and the model is repeatedly proven in many objects throughout the world.

Considered six options modeling the construction of three sections of the experimental building, the description of which is clearly demonstrated in figure 3, where percentages are the number of floors built.

Stage	№ section	The estimated case					
		1	2	3	4	5	6
1	1	100%	100%	0%	44%	44%	0%
	2	100%	0%	100%	44%	0%	44%
	3	100%	0%	0%	44%	0%	0%
2	1		100%	100%	72%	72%	44%
	2		100%	100%	72%	44%	72%
	3		0%	0%	72%	0%	44%
3	1		100%	100%	100%	100%	72%
	2		100%	100%	100%	72%	100%
	3		100%	100%	100%	44%	72%
4	1					100%	100%
	2					100%	100%
	3					72%	100%
5	1					100%	
	2					100%	
	3					100%	

Figure 3. The sequence of construction of the building

3. Results

When analyzing the stress-strain state of the base, taking into account the joint work, it is customary to consider such parameters as contact stresses on the base of the foundations and their draft. The results of the estimating of changes in these parameters is shown in figures 4-9, which shows the parameter value in percent relative to the minimum values of the six calculated cases.

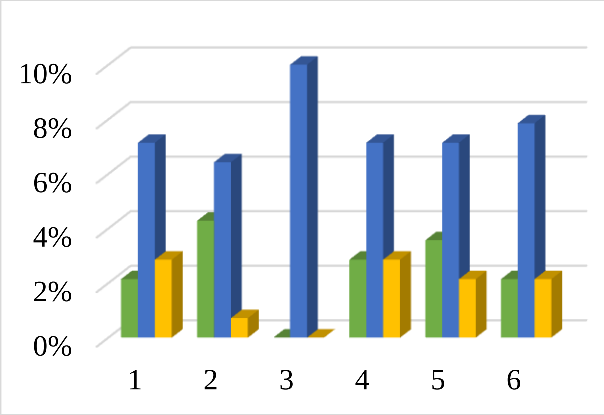

Figure 4. The results of the analysis of mean settlement of the structure. In all calculated cases, the value of the studied parameter is more at the middle section

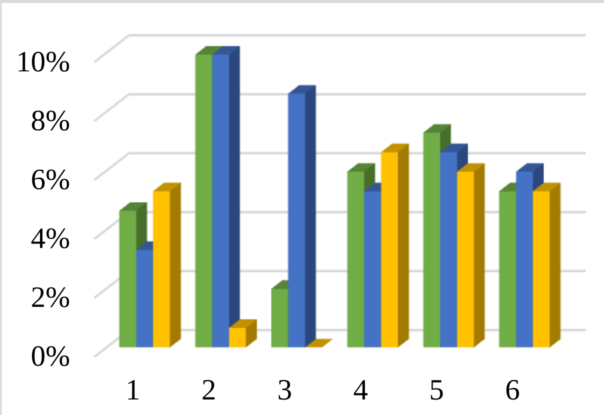

Figure 5. The results of the analysis of maximum settlement of the structure. In the calculated cases 2 and 3, the results of the study differ to 10%, and in the calculated cases 1, 4, 5 and 6 the results vary within 2%

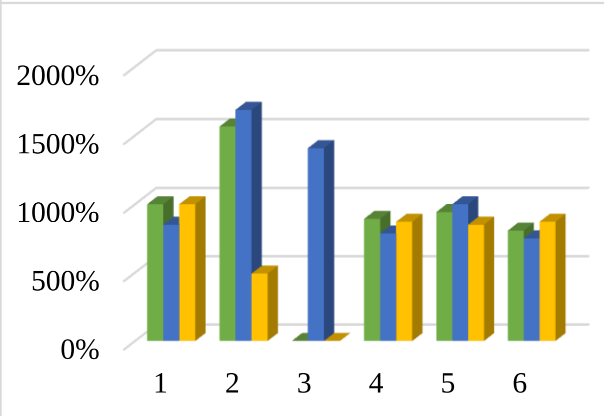

Figure 6. The results of the analysis of differential settlement. The lowest value of the studied parameter was observed in calculated case 3 at the extreme sections, and the greatest value in the calculated case 2 in the middle section

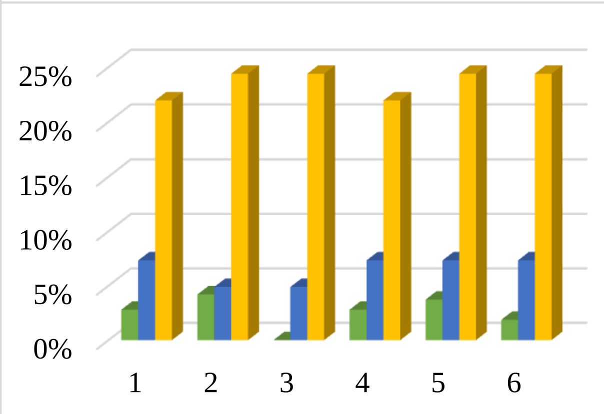

Figure 7. The results of the analysis of mean footing contact pressure. In all calculated cases, the difference in the results of the studied parameter to 3%

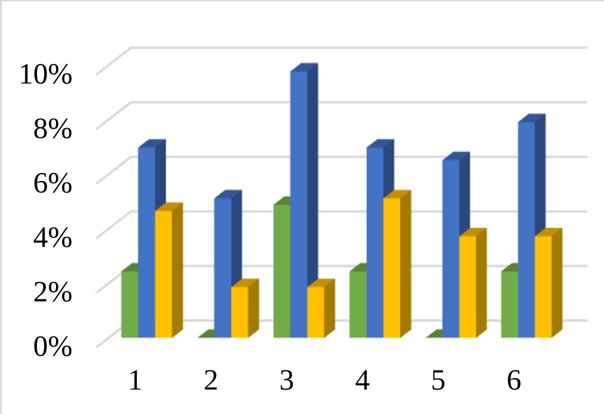

Figure 8. The results of the analysis of minimum footing contact pressure. The greatest value of the investigated parameter in all calculated cases is observed in the middle section

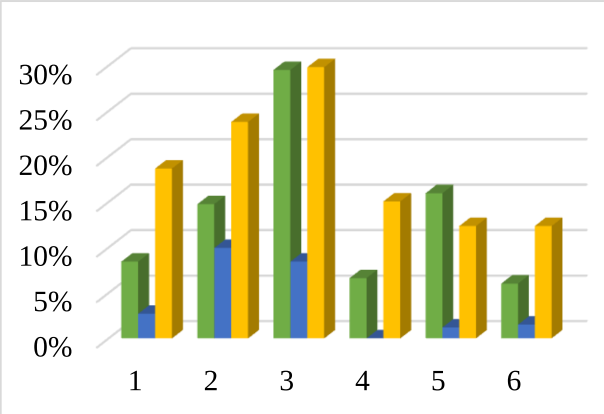

Figure 9. The results of the analysis of maximum footing contact pressure. The greatest value of the investigated parameter in all calculated cases is observed in the extreme sections, and the smallest value in the middle section

4. Discussion

Having considered the stress-strain state of the "foundation-foundation" system, we can note some of its features:

- the difference between a phased and "instant" download, i.e. when comparing the calculated cases 1-4, 2-5 and 3-6, mainly reduces to the effect on differential settlement (from 1 to 9.7 times) and maximum footing contact pressure to 24%
- the sequence of construction of sections is characterized by a comparison of the calculated cases 1, 2, 3 and 4, 5, 6, and mainly affects the parameters differential settlement (from 1.2 to 10.4 times) and maximum footing contact pressure (from 3% to 21%)
- in the stage-by-stage erection of a building, the parameter maximum footing contact pressure has lower values than for the "instantaneous" one
- the construction modeling method did not affect the localization of the extrema of the function maximum footing contact pressure
- in the calculated cases 2 and 3 the maximum values of the parameter differential settlement are approximately 2 times larger, and the minimum values are much less than in cases 1, 4, 5, 6

5. Conclusions

Because of performed studies, we can draw the following conclusions:

1. With increasing loads on the foundation of the experimental building, in the numerical experiment there are significant changes in such investigated parameters as the relative difference in precipitate differential settlement and the maximum values of contact stresses $\sigma_{z,max.}$, which indicates the influence of the loading method on the stress-strain state of the substrate. The effect of the experiment on the other parameters considered is unimportant.

2. When modeling the sequence of erection of a monolithic full-frame multi-section building, it is necessary to take into account the gradual increase in the loads on the foundation plate.

Acknowledgments
This work was financially supported by Ministry of Education and Science of the Russian Federation (#NSh-3492.2018.8).

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