UDC 624.131

PECULIARITIES OF SELECTION OF CALCULATED PRIMARY MODELS AT THE NUMERICAL INVESTIGATION OF THE FOUNDATION UPPER STRUCTURE SYSTEM

ANASTASIYA LASTOVSKAYA, NATALYA LOBACHEVA
Polotsk State University, Belarus

The principles of calculating basis and foundation deformations according to the national and European norms are given. According to European norms, the limiting states of USL and SLS are considered. The similarities and differences in the calculation principles of the deformations of the bases and the foundations of shallow deposits according to European and national norms are revealed and generalized. The theoretical bases of each of the considered models are given in the article. To select a model that meets the requirements of calculations accuracy and costs minimization, a comparative analysis of common soil models described in the scientific literature and used in calculations of settlement and dynamic effects of buildings is carried out.

Introduction. Ensuring the reliability of the building structure with the minimum cost of materials is largely determined by the degree of accuracy of the base soil model choice, most plausibly reflecting the deformation properties of specific soil massifs. In the modern construction practice, according to the regulatory documents [1, 2], calculation is carried out for two groups of limiting states (on bearing capacity and deformations). These calculations verify only the limiting states when achieving the structural elements of the structure, the construction as a whole or its base ceases to meet the specified operational requirements [7].

When calculating the structures of the buildings operated in the conditions of an unevenly deformable basis, an important task is to determine the reactive (contact) pressures in the ground. The values of internal forces and the size and strength of the cross-sections of the building's structures directly depend on the nature of the distribution of contact pressures. To determine the contact pressures in the foundation of structures, as a rule, calculation models that schematically describe the natural mechanical properties of the ground environment are used. It is necessary to take into account the properties of the soil bases, which depend not only on the conditions of their natural occurrence, but also on the stress state, enabling the researchers to create a large number of different models of the soil foundation. At present, the use of numerical calculations of the basis-foundation-upper structure system with the use of software-computing complexes such as SCAD Office, Lira, Robot Structural Analysis, Plaxis, Ansys, Abaqus and others is becoming increasingly widespread. In these software complexes, various models of the ground base have been implemented [9].

Analysis of recent achievements and publications. In [3, 4, 8] the specific features of computational basis models and buildings and the methods of evaluating their stiffness characteristics are presented. In addition, the iterative principles of accounting for the joint work of the building and the foundation and ensuring the reliability and durability of buildings as elements of the "foundation-construction" system are shown in these works. The article [9] determines and compares the sediment values of the structure obtained from the results of the application of the normative technique of SP 22.13330.2011 with precipitation obtained from the results of application of various soil models implemented in the SCAD Office and Plaxis 3D software complexes. In [6], a technique is proposed and an algorithm for solving the problem to determine the probability of exceeding the boundary deformations of the "building-foundation" system is developed. In the book [5] various kinds of finite elements of basis modeling and examples of the basis numerical modeling by the finite element method are offered.

Allocation of the previously unresolved parts of the common problem. Despite the increased interest of well-known scientists in the selected problems, the choice of the base soil model, most plausibly reflecting the deformation properties of specific soil massifs, does not lose relevance. These issues remain undisclosed in full, which requires their further development.

Objective. To identify the features of the application of various soil models for the further numerical study of the "basis - foundation - upper structure" system.

Main part. The bases, foundations and upper structures work together and should be designed as one single whole. To design such a system, one should evaluate the features of the entire system operation and each of its component parts separately.

The most common in the design practice of joint methods of designing bases, foundations and supra-fundamental structures, i.e. system basis - foundation – upper structure, have two groups:

1. Comprehensive joint calculation of the above-ground structure, foundation and soil basis.

2. Use of the data of the foundation permissible movements, corrective coefficients and recommendations that take into account the rigidity of the structure in the design of bases and foundations.

The first group of methods considers the construction, foundation and basis as an indivisible, jointly deformed whole. At the same time, various calculation schemes or calculated idealizations of upper structures, foundations and bases are used.

The calculation of the system is as follows. First, the frame on non-deformable supports is considered. From the forces acting on the structure and the effects, the reactions of the supports are determined, according to which, in compliance with the calculated formulas, the dimensions of the foundations are assigned and the corresponding displacements of the bases are calculated. Then the frame on elastically compliant bonds is calculated, and the values of the base displacements are determined, which is compared to the deformations of the basis under the same loads. In the design process, the dimensions of the foundation structure and the rigidity of the ties can be corrected. As a result, when designing by successive calculations, it is necessary to achieve the state when the deformations of the base and the displacement of the foundation are close to each other.

The second group of methods combines techniques for assessing the joint work of the basis and the upper structure, in which the rigidity of the upper structures is accounted for approximately by correcting coefficients and classifications of rigidity structures. Such methods are developed in the norms for designing the foundations of buildings and structures [1, 2] and are most often used in practice because of their simplicity. In fact, these methods use the principle of estimating the limiting states of structures by generalized deformation criteria, which are established either experimentally on the basis of statistical processing of the results of the field observations of the buildings and structures settlement, or on the basis of a preliminary calculation of the structure for the displacement of the supports. For example, to assess the strength of structures in a frame building, it is sufficient to calculate the difference in its foundations settlement and compare it with the permissible value recommended by the standards or a standard design.

To assess the stress-strain state of the base, it is necessary to have a model of soil that will allow us to predict mathematically the behavior of the soil mass in case of various types of loads. The essential complexity of the foundation construction problems is that they, as a rule, are not one-dimensional, i.e. the ground base is in a complex stressed state.

Different models of soil base can be divided into the following groups:

- models based on Winkler's hypothesis of direct proportionality between pressure and draft;
- models that treat the soil as a homogeneous, elastic solid;
- combined models and models of an intermediate character between the Winkler hypothesis and the hypothesis of an elastic half-space.

In models based on the Winkler hypothesis, they are based on direct proportionality between the pressure on the elementary area and its vertical displacement. This dependence was proposed by Winkler in 1867. On its basis in the 80s of the 19 century, Zimmerman proposed the method of the bed coefficient to calculate the railway track, which became the prototype of all the subsequent models of this group.
In the model proposed by Pasternak P.L., the mechanical properties of the soil base are described by two bed coefficients. The first coefficient C1 characterizes the resistance of the base to compression and is measured in kN / m3; the second coefficient C2 – characterizes the resistance of the base to the shear and is measured in kN / m. The resistance to shear is due to the presence of cohesion and internal friction between the soil particles. The foundation settlement is counteracted by the reactive pressure P distributed around the sole and the stresses distributed along the outline of the sole, which are associated with vertical displacements through the coefficient C2.

In models that regard the soil as a homogeneous elastic solid body, in accordance with the solutions of the theory of elasticity, it is necessary to consider three problems: spatial, plane and axisymmetric. For tape foundations, the solutions of a planar and spatial problem are used.

In the spatial problem, the ground base is regarded as linearly deformed half-space bounded from above by a horizontal plane. In the plane problem, the ground base is considered as a linearly deformable half-plane. The base in the form of a half-plane can be conditionally separated from the half-space by two parallel vertical planes.

Klepikov S.N. [10] proposed a model for the variable stiffness coefficient, which is defined as the ratio of the mean design pressure P (x) at the point x of the foundation to the sediment of the base S (x) at this point. The sedimentation of the base S (x) is determined by conventional methods (the method of layerwise summation, the method of a linearly deformed layer). The distribution of the normal pressures along the depth at any point x within the basis of the basement is determined using the method of corner points. It is assumed that only elastic deformations of the soil have distributive properties, and plastic deformations do not possess this property. In this connection, the total settlement of the basis S (x) is divided into elastic Se (x) and plastic Sp (x), determined by the method of layerwise summation using respectively the residual (plastic) strains modulus Epl and the elastic strain modulus Eel. These modules are determined by the results of field tests of the soil with dies or laboratory compression tests taking into account loading and unloading trajectories. Taking into consideration the described features, the stiffness coefficient is obtained not only by the physical properties of the soil, but also by the variable, that reflects the deformability of the basis only under a concrete foundation or its section. However, in real conditions, the arrays are composed of separate, essentially different soil layers whose thicknesses are not the same on the building spot. Some of the structures have different depths, and the strength and deformability of the soils and structural elements differ by several orders of magnitude.

Thus, the use of the theoretical apparatus of classical theories to solve practical problems of geotechnics is impossible in many situations. For such cases, it is necessary to use numerical methods and the most common finite element method (FEM) in the calculation practice in particular.

Conclusions:

1. With all the advantages of modern elastic-plastic models, they do not adequately describe the regularities of soil behavior when they are compacted with different schemes and loading rates. The technique for determining their parameters for specific soil variants remains difficult for engineering practice.
2. It is also necessary to take into account the fact that when determining the stresses in a soil massif with the use of the theory of elasticity, assumptions are made that regard the soil as a linearly deformable isotropic body experiencing a one-time loading. When the same structure interacts with the unevenly deformed basis, the soil mass works under conditions of complex loading, in which both the separation of the foundation from the basis and the development of plastic deformations are possible. Therefore, in order to solve contact problems under conditions of uneven deformations of the base, it is necessary to perform calculations by the method of successive loading with iterative refinement of the rigidity of the basis at each load level, for example, in the calculation systems SCAD Office and Plaxis 3D.
3. On the basis of the already existing ground base models, the ground base model of the particular ground conditions in Vitebsk region of the Republic of Belarus will be elaborated, which will later be applied for the joint calculation of the "basis-foundation-upper structure" system.

REFERENCES

1. Foundations. Design rules : TCH 45-5.01-67-2007 (02250) – Enter. 02.04.2007. – Minsk : Ministry of Architecture and Construction of the Republic of Belarus, 2008. – 140 p.
2. Bases and foundations of buildings and structures. Basic provisions. Construction standards of design : TCH 45-5.01-254-2012 (02250). – Enter. 01.07.2012. – Minsk : Ministry of Architecture and Construction of the Republic of Belarus, 2012. – 102 p.
3. Garagash, B.A. Reliability of spatial controlled systems "base-construction" with non-uniform deformations of the base : in 2 vol. / B.A. Garagash. – M. : Publication ASV, 2012. – Vol. 1. – 416 p.
4. Garagash, B.A. Reliability of spatial controlled systems "base-construction" with non-uniform deformations of the base : in 2 vol. / B.A. Garagash. – M. : Publication ASV, 2012. – Vol. 2. – 472 p.
5. Lees, A. Geotechnical Finite Element Analysis. A practical guide / A. Lees. – London : ICE Publishing, 2016. – 278 p.
6. Kichaeva, O.V. "Building-base" system boundary deformations due to probabilistic estimation methodology / O.V. Kichaeva // Academic Journal. Series: Industrial Machine Building, Civil Engineering. – Issue 2 (49). – Poltava : PoltNTU, 2017. – P. 61–69.
7. Vinnikov, Yu.L. Імовірнісні methodology in geotechnical engineering / Yu.L. Vinnikov, M.O. Kharchenko // Zbirnik naukovyh prac. – Poltava : PoltNTU, 2015. – V. 1 (43). – P. 93–111.
8. Handbook of geotechnics. Foundations, foundations and underground structures / ed. V.A. Ilyichev and R.A. Mangusheva. – M. : Publisher ASV, 2014. – 728 p.
9. Soil models implemented in the SCAD Office and Plaxis 3D software complexes / A.V. Egorova [et al.] // Construction of unique buildings and structures. – 2016. – №3 (42). – P. 31–60.
10. Klepikov, S.N. Calculation of structures on a deformable base / S.N. Klepikov. – К. : NIISK, 1996. – 204 p.