ASPECTS OF INTERWORKING STRUCTURE-FOUNDATION-FOUNDATION SOIL FOR SPECIAL CONSTRUCTIONS

ASPECTE ALE CONLUCRĂRII STRUCTURĂ-FUNDAȚIE-TEREN DE FUNDARE LA CONSTRUCȚII SPECIALE

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Abstract: *Choosing the type of structure and foundation appropriate to soil category on which is located the construction, is one of the hardest problem of structural engineering. The interaction between structure - foundation - soil (ISFS) represents the behaviour and respond way at the loads of ensemble construction-soil, considered as a unity, compound from constituent parts that have different geometrical and mechanical characteristics and between there exists a continuous process of redistribution of efforts during the progressive increasing of unequal settlement of supports, till the final values.*
The great variety of constructions structures, geotechnical properties of soils foundations, as many factors and parameters that interfere, it makes the results obtained by classical methods not to present satisfying correspondence between the theoretical an practical results. Hence, it results the conclusion that it's necessary to give a particular importance of theoretical and practical determination of parameters and factors that interfere in an inter-working calculus.

Rezumat: *Alegerea tipului de structură şi de fundaţie, corespunzător categoriei de teren pe care este amplasată construcţia, este una din problemele cele mai grele ale ingineriei structurilor. Interacţiunea structură-fundaţie-teren (ISFT) reprezintă modul de comportare şi răspuns la încărcări ale ansamblului construcţie-teren, considerat ca o unitate, compusă din părţi componente ce au caracteristice geometrice şi mecanice diferite şi între care există un proces continuu de redistribuire a eforturilor în timpul creşterii progresive a tasărilor neegale ale reazămelor, până la valorile finale. Varietatea mare a structurilor de construcţii, a proprietăţilor geotehnice ale terenurilor de fundare, precum şi multitudinea de factori şi parametrii care intervin fac ca rezultatele obţinute prin metodele clasice să nu prezinte o concordanţă mulţumitoare între rezultatele teoretice şi cele practice. De aici, rezultă concluzia că este necesar a se acorda o importanţă deosebită determinării teoretice şi experimentale a parametrilor şi factorilor care intervin într-un calcul de conlucrare.*

Key words: *structural engineering, geotechnical properties, unequal settling of supports*
Cuvinte cheie: *ingineria structurilor, proprietăţi geotehnice, tasări neegale ale reazămelor*

INTRODUCTION

The problem of inter-working between construction and soil is a natural phenomenon that takes place when human being interferes on the soil by building a construction. The study of interaction between structure-foundation-soil began almost 70 years ago. It has to be noticed that in the last years, the foundation soils considered "good soils" are difficult to be found and it appears the necessity of building on soils considered up to now improper to the constructions, but it can become good foundation soils by different improvement soil methods.

Choosing the type of structure and foundation appropriate to soil category on which is located the construction, to serve a certain scope, to use a certain technological flow and to respect principles that will allow its future development is one of the hardest problems of structural engineering. Solving it in an optimum way depends on the design engineer gift, but in as much as knowledge that he has it about the construction location, geological and hydrological conditions, soil nature and its deformability, disposable materials, equipment and technical possibilities to erect etc.

MATERIALS AND METHOD

To calculate a construction, taking into consideration the interaction between construction and the foundation soil, considered to have elastic and rheological properties, a great importance should be made to the behaviour way of earth massive. This calculus can be resumed at the obtaining some mathematical relations that represent the capacity for deformation of contact surface, respectively the assignment of reactive pressure on this surface. Thus, it can be appreciate that the mentioned above sayings characterise enough the response of the building and foundation soil at the exterior loads. But for a proper calculus of interaction construction-soil, the biggest difficulty represents the appropriate scheme choice that represent the behaviour of soil massive, pointing out that this scheme has to be characterised by a small number of parameters making easier this calculus.

The interaction between structure-foundation-soil (ISFS) represents the behaviour and respond way at the loads of ensemble construction-soil, considered as a unity, compound from constituent parts that have different geometrical and mechanical characteristics and between there exists a continuous process of redistribution of efforts during the progressive increasing of unequal settling of supports, till the final values. For static indeterminate frames with isolated foundations located on an un-deformed foundation soil and using the conventional methods of calculus it results the following moment diagram:

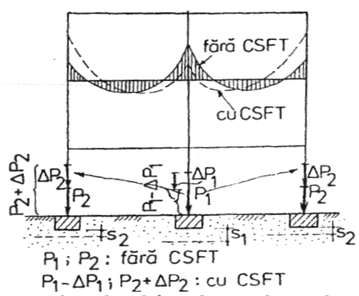

Figure 1. Static indeterminate frame with isolated foundations located on an un-deformed foundation soil using the conventional calculus

If we consider that the structure is located on a deformable foundation soil, than by the settlement of central column, the state of efforts and deformations is changed (meaning that the marginal columns are supplementary loaded and the effort in central column is decreased). In this case, the bending moment on central support is decreasing and the bending moments on the marginal columns is increasing. In current practice, the design engineers determine the state of efforts and deformations of the structure using the conventional calculus by not exceeding the admissible pressure on the foundation soil, respectively the maximum admissible strength and deformation capacity considered to be admissible at structure exploitation. The supplementary efforts that appear because of unequal settlement of the supports are in many cases neglected at designing phase, the design engineers don’t know the measurement order of the errors resulted by this simplification calculus.

The complex behaviour of the construction materials, mostly the material called “soil” can be described only through an idealisation of their properties, introduced by some calculus hypothesis. The mechanical properties of soils are ranging between the plastic clays and the most cleaned, perfectly dried sands. Introducing some hypothesis that leads to the elasticity theory, the soil is assimilated to a continuous, homogeneous, elastically and isotropic medium is the only way to solve the problem of continuous deformable mediums.

The first hypothesis used is that of continuous medium, perfectly usable for studies at macroscopic scale of phenomena as it is the calculus of foundations located on deformable soils. From physical point of view, the soils are dispersed mediums compound of liquid, gaseous and solid phase. The concept of continuous is a mathematical fiction, but when it is applied to the study of solids and fluids mechanics, it is supposed that the material properties can be considered an infinitesimal volume.

The elastic medium hypothesis considers that the material has the capacity of storing mechanical energy without its dissipation; the material being able come back to its initial form after the producing cause is removed. In this hypothesis there is a linear dependence between deformations and tensions. For soils, the relationship effort-deformation can be accepted as linear only for a range of pressures of whose superior limit don't exceed to much the values of the pressures transmitted by the construction to the soil. Hence, the hypothesis of deformable linear body is accepted for some soils up to a certain measure of load.

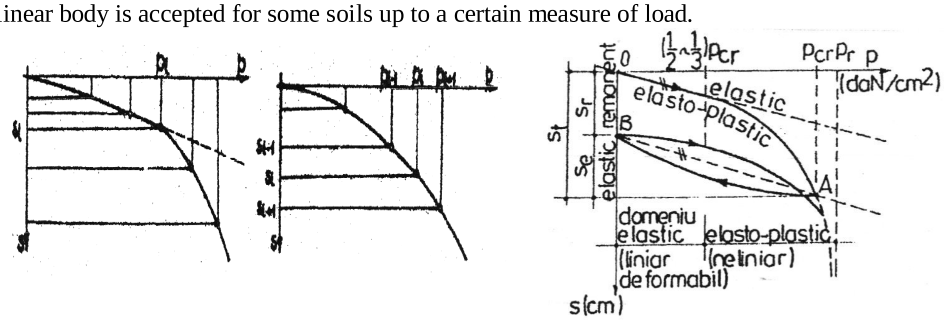

Figure 2. Elastic and elastic-plastic domain in the elastic medium hypothesis for deformable soils

The most correct way of separation the elastic domain (linear deformation domain) from the elastic-plastic domain is the achievement of different cycles of soil loading-unloading using laboratory or field testing. For soils, $s_r \geq s_e$ (remnant deformation is greater than the elastic deformation) and to determine the domain of the elastic behavior for the first step of loading, through the point O it is traced a parallel to the straight line AB. Thus, on the proportionality sector between load and deformation there can be written the generalized Hooke law, as it follows: $\{\sigma\} = [D] \cdot \{\varepsilon\}$, where:

$$\{\varepsilon\} = \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{Bmatrix} \quad \{\sigma\} = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix} \quad [D] = \begin{bmatrix} 1-\nu_t & \nu & \nu & 0 & 0 & 0 \\ \nu & 1-\nu_t & \nu & 0 & 0 & 0 \\ \nu & \nu & 1-\nu_t & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1-2\nu_t}{2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1-2\nu_t}{2} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1-2\nu_t}{2} \end{bmatrix}$$

$\{\varepsilon\}$- specific deformation tensor; $\{\sigma\}$-normal tension tensor; ν-Poisson coefficient; D-elasticity matrix.

The general elastic model leads to mathematical problems of extremely difficulty, that's why it is not used in current practice. Thus, it was necessary to introduce some simplifying supplementary hypothesis, like isotropy and homogeneous hypothesis.

The isotropy hypothesis considers that the mechanical properties of the material in a point don't vary with the direction; in other words the material properties are the same in any direction in a certain point. The model of elastic linear homogenous and isotropic semi-space of Boussinesq, represents the basis of calculus of girders on elastic medium, being the most simplifying hypothesis. For soils, there have been studied two types of non-homogeneities.

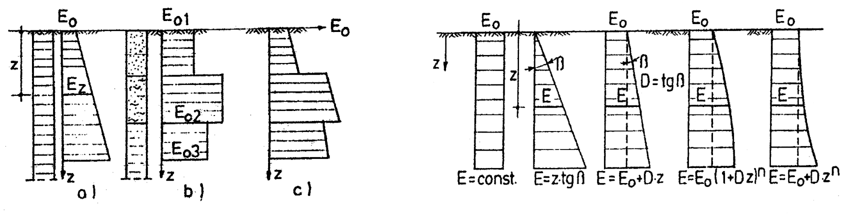

Figure 3. Isotropy and homogenous hypothesis for deformable soils

There have been studied two categories of non-homogeneities:

- the semi-space is considered to have a linear deformation modulus, variable along the depth (fig. 3a);
- the semi-space is stratified, each layer being homogenous and having the same value E_0 of linear deformation modulus on length and depth, but modifying accordingly at the passage to the next layer (fig. 3b).

In reality, the stratified soils are discontinuous non-homogenous mediums and their deformation modulus E_{0i} is variable along the layer depth. To eliminate the complications introduced by the consideration of a stratified medium, the soil is considered a homogenous soil having an equivalent linear deformation modulus. Taking into consideration the variation on depth of linear deformation modulus leads to the concentration of deformations under the loaded foundation foot and thus, reducing the value of computed settlements.

SOIL MODELLING FOR FOUNDATION ELEMENTS CALCULUS

Most of the paper works concerning the study of statically behaviour of the assembly construction-soil talks about the classical problem of beams or plates on elastic medium. Other category of paper works solves the interaction construction-soil assimilating the construction with a beam of equivalent rigidity. In classical methods, the foundation soil is assimilated with Winkler model (the model of bed coefficient) or with Boussinesq models (the model of elastic semi-space).

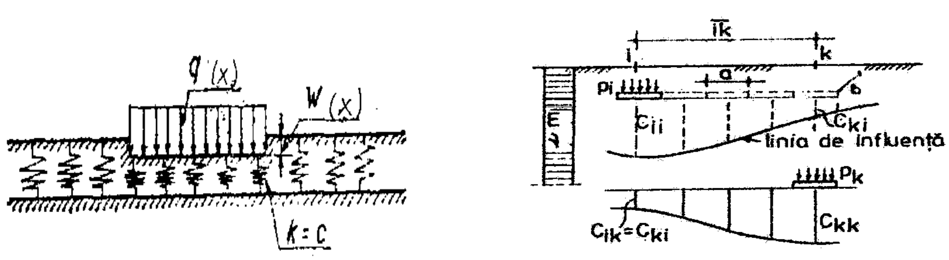

Figure 4. Winkler model and Boussinesq model

The foundation is considered to be a deformable element supported by a deformable medium. Winkler model is based on the theory of local elastic deformations, considering that the foundation soil deforms only in the limits of the loaded area. This model assimilates the soil with a continuous elastic medium, in which the reaction in any point is proportionally with the local settlement. The proportionality constant K_s between the reaction and the settlement, is the parameter that characterise the model and is currently named, bed coefficient.

The main critique of the domain specialists starts from the observation that the foundation soil settlement in a point doesn't depend only of the pressure from that point, but also of the pressures from the neighbouring points, the settlement of the soil not being a local one, but a generalised one, thus the settlement exists also outside the loaded area. But, the soil settlement depends also on the soil nature and on the loading surface shape, which makes the value of bed coefficient to have many characteristics.

The model proposed by Boussinesq in 1867 consists in assimilating the earth massive with a semi - space elastic, linear, homogenous and isotropic, on which the deformations of foundation soils extends outside the foundation contour. The experimental works made on cohesive soils shows that his theory is accordingly with the reality because on rigid foundations there is a good elastic behaviour of foundation soils.

In 1922 Wieghardt proposed the assimilation of foundation soil with a sequence of arches supported on a rigid soil, bounded at the superior side with a wire subjected to tension. The rigidity of arches at the compression is constant and equal to bed coefficient value. Wieghardt model can be used for the modelling of cohesive soils, but there is not adequate for sandy soils whose repartition capacity can be neglected. Because the idea of bonding the arches belongs to Wieghardt, all the other models developed on this way we say it derives from his model.

RESULTS AND DISCUSSION

For certain destinations of industrial and agricultural constructions, the practice imposed, based on experience, certain types of structures as silos, water castles, cooling towers, smoke chimneys, etc.

Foundation of these structures, foundation mats or continuous foundations slabs have to be adapted to each location depending on the nature and deformability of the soil, on the size and distribution of reactive surface contact and on general deformation of the construction. The efforts that appear following the unequal settlements of soil foundation can be mostly taken over by the foundation, but in the case of some sufficiently rigid constructions are taken by the assembly structure-foundation.

Silos are very heavy constructions and they bring great loads to the foundation soil surface. In almost all the cases the foundation of a silo is a general mat foundation because this solution accomplish a stiffness of the entire construction and uses the entire bearing capacity of the soil where is located. The accidents appear mostly because of breakage of the foundation or of superstructure bending, silos being very heavy constructions. Mat foundations are used when it has to be supported heavy loads from the superstructure to the soil, or when the bearing capacity of the soil is reduced, thus being assured a minimum pressure on the soil and homogenising the unequal settlements considering the modification of reactive pressure on the contact surface.

Smoke chimneys foundations are smaller than the others industrial constructions, usually being round or polygonal plates, rigid and made of reinforced concrete with a constant or variable thickness; sometimes it can be 4-5 m depth caused by the shearing efforts that appears between them.

A special attention should be given to the foundation on clayey soils where the reactive pressure is twice bigger than the medium pressure and sometimes it can be exceeded the maximum bearing capacity of the soil causing the bending or loosing the stability of the entire assembly by ejecting the foundation soil.

The cooling towers have the infrastructure as a lattice girder on the shape of a continuous circular or polygonal ring in which are clamped the columns. In speciality literature, there are not mentioned accidents or breakage of their foundations.

For an optimum design of the constructions with general mat foundations or continuous foundations, on deformable soils, first it has to be established the foundations dimension and the foundation depth from the condition that the earths massive has to be capable to support the load transmitted by them without the appearance of sliding. In the case of soils without cohesion (sand) and in the absence of supplementary loads, the bearing capacity increases proportionally with the width of the beam in the case of continuous foundations, or with the size of mat foundation surface.

CONCLUSIONS

For non-cohesive soils (sands), the reactive pressure is maxim in the center of contact surface and decreases with the increasing of foundation dimensions and foundation depth, having an almost uniform distribution on the contact surface.

For cohesive soils (clays), the reactive pressure is bigger at the foundation sides than in the centre of the surface contact. That's why for great surfaces, the calculus with a uniform pressure on a contact surface becomes dangerous, for the constructions based on clays. The bending moments that appears in foundations is bigger than those resulted in the conventional calculus.

In conclusion, the reactive pressure on the contact surface can be considered uniformly distributed in the case of constructions with great rigid surface foundations located on sands. In the case of clayey soils, the reactive pressure has to be determined in a calculus of inter-working construction-soil because they have great values on the foundation sided against the medium pressure on the foundation base; it can lead to the loss of the earth massive stability by exceeding the maximum bearing capacity.

The general deformation of the constructions located on sands appears at the top or bottom of the superstructure because the settlement is bigger on sides and smaller in the centre, the contact surface having a convex shape. The general deformation of the constructions located on clays comprises cracks at 45^0 angles starting from the corners to the upper part of the building or starting from the centre closing up on height. At the superior part the breakage is made by compression and the settlements are bigger in the middle of the contact surface and decreases towards the sidings.

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