Structure-Soil Massif System Behavior Features Under Static & Dynamic Loads

Les particularités du comportement du système edifice-sol avec des efforts statiques et dynamiques.

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ABSTRACT: The effect of existence of the critical time of loading on structures that contact with soil due to rheological properties of concrete and soil is identified in the thesis. Settlement of foundations under dynamic load has been analyzed in the paper. Dynamic Hereditary creep theory suggested to forecast foundations settlements under dynamic load. The approximate convergence of experimental and theoretical data, obtained by means of hereditary creep theory, has been found out.

RÉSUMÉ : Au cours du travail il est révélé un effet d'existence d'une durée critique de charge des charpentes qui sont en contact avec le sol, à cause des propriétés rhéologiques du béton et du sol. Dans cet article est analysé l'abaissement des foundations aux efforts dynamiques. L'emploi de la théorie héréditaire du fluage est considéré pour la provision de l'abaissement des fondations aux efforts dynamiques. On a découvert une concordance très proche des donnés théoriques obtenues a l'aide de la théorie héréditaire du fluage avec des donnés expérimentales.

KEYWORDS: soil, foundation, vibrocreep.

1 CRITICAL TIME OF LOADING A "BASE-FOUNDATION" SYSTEM DEFORMING OVER TIME

The stress-strain state of the "base-foundation" system at the initial instant corresponds to an elastic structure on elastic foundation, and when further deformed by a constant external load – to the same structure, but with long-term modules of the foundation and base materials. At that, A.R. Rzhanitsyn (Rzhanitsyn 1949), along with other authors, assumes that the worst values of forces in the foundation structure manifest themselves from the elastic-instantaneous solution and the creep theory solution at time t→∞, maximal distant from the loading moment. In (Luchkovskiy 2000), using the Winckler model as an example, we showed that due to different creep leak rates in the foundation structure (concrete) and the base, the worst forces manifest themselves in some, short enough, time after the start of the foundation loading, which is the «critical time of loading» of the «base-foundation-structure» system.

In order to generalize regularities of the revealed phenomenon for the soil base, possessing a distributive capability, we shall deal with the base, having selected as a model the discrete model (Luchkovskiy 2000), developed by us (flat variant).

We take into account rheological properties of the foundation structure and the base using algebraization of integral equations of the creep theory (Luchkovskiy 2000), (Ulitskiy 1967). For example, when using assumptions of the «ageing» theory and stress function $f[\sigma]$ of the form

$$f[\sigma]=\sigma+\beta\cdot\sigma^2 \qquad (1)$$

the time module of deformation of the uniaxially deformed material E_t can be presented as the relation

$$E_t=\frac{2E_0}{\varphi_t\left(\dfrac{\sigma_0}{\sigma_t}+1+\dfrac{2}{\varphi_t}+2\beta\sigma_0\right)}, \qquad (2)$$

In the research below we assume:

For foundation concrete – $\varphi_\infty=3.0$, $b=0.04$ day^{-1}; $\beta=0$; $E_b=23000$MPa;

For base soil – $\varphi_\infty=2.0$, $b=0.325$ day^{-1}; $\beta=5$MPa^{-1}; $E_0=10$MPa.

We have sequentially considered three processes of deformation of the «base-foundation» system:

when taking into account linear creeping of the foundation material;

when nonlinear creeping of the base soil shows up;

at simultaneous creeping of foundation and soil body materials.

All calculations are made numerically for different time moments of sustained applying of constant load. At that, in the interval $0\leq t\leq 20$ of the day, calculations were made every other day, after that – every 10 days during half a year.

Long-term stiffness B_t of the foundation beam with unilateral reinforcement $A_s=40$cm^2 with a cross-section of b=1m; h=0.35m, was found using the formula obtained by I.I. Ulitskiy (Ulitskiy 1967)

$$B_t=A_s\cdot E_s\cdot h_0\left(h_0-\frac{x_0}{3}\right)\eta_t, \qquad (3)$$

The time variation of concrete and soil creeping properties, presented in Fig.1, shows that the base creep rate is considerably higher than the concrete creep rate, which determines the nature of variation of the stress-strain behavior of the contacting system. If, according to relation (see Eq. 2), the foundation and base stiffness is presented as

$$B_t = \overline{B}_t \cdot B_0; \;\; E_t = \overline{E}_t \cdot E_0, \qquad (4)$$

their relationship can be easily written as

$$\frac{E_t}{B_t} = K_t \cdot \frac{E_0}{B_0}, \qquad (5)$$

where K_t is the coefficient of the time variation of the relationship between the base and foundation stiffness, depending on the creep leak rate in the foundation and base, on the level of their stress state, load duration etc.

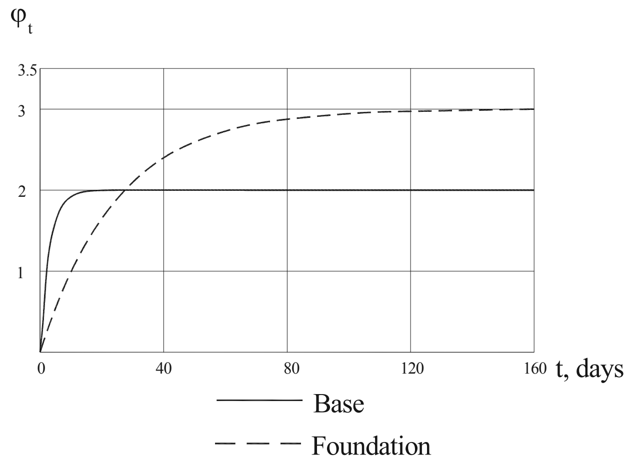

Figure 1 – Chart of time behavior of creep properties of base soil and foundation concrete

If, for example, the mean stress in the soil for the foundation under consideration is assumed to be equal to σ=0,2MPa, a different time behavior of K_t will be obtained for all three processes of loading the «base-foundation» system under consideration (See Figure 2).

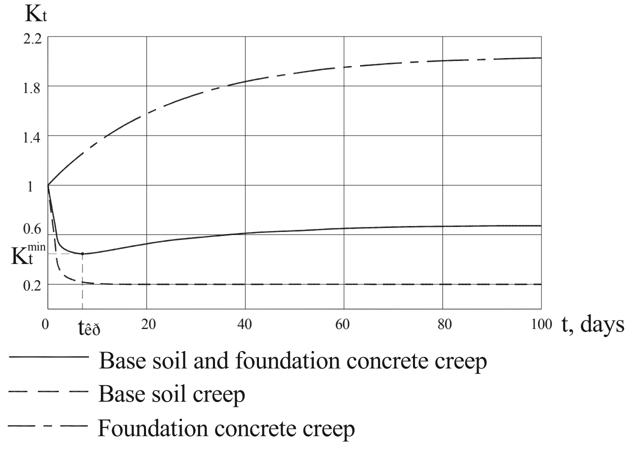

Figure 2 – Coefficient of base stiffness–to-foundation stiffness relation time variation.

It is easy to note that $K_t \geq 1$ grows over time with development of the foundation material creep, with the base creep manifestation (consolidation), $K_t \leq 1$ – decreases, and at simultaneous manifestation of rheological properties of the foundation and base, there is a certain critical loading time tcr, corresponding to the minimum value $K_t = K_{tmin}$. Consequently, the moment of sustained loading, corresponding to the critical time $t = t_{cr}$ may turn out to be the worst in terms of force distribution in the system.

2 FOUNDATIONS SETTLEMENT UNDER DYNAMIC LOADS

The dynamic loads caused by machinery operation can lead to weak decaying machinery foundations settlements which can often be quite substantial and uneven.

The available observational and experimental data obtained while facilities were being subjected to dynamic loads indicate that such settlements can cause buildings and structures damages and the machines involved in the same technological process dysfunction (Aleksandrovych 2012).

2.1 *Foundation settlement forecast using heritable creep theory*

Soil massif provided with linearity in the dynamic tasks and its rheological properties are estimated from the solution of energy balance equation or heritable mechanics of deformable bodies.

The second case is considered in the paper. According to Volterra`s approach, who interprets operators as constants, the solution consists in a form of elastic constants and coordinates function multiplication by function of time. Relying on known Schleicher’s solution, the relation of stamp settling on linearly elastic heritable half-space under fixed constant load is presented in the following way:

$$S(t) = \frac{\omega b(1-\upsilon^2)\sigma_{cm}}{E}\left[1 + \int_0^t K(t-\tau)d\tau\right], \qquad (6)$$

where $K(t-\tau)$ – is a creep kernel (Khain 1977, Savinov 1979).

According to Boltzmann, who was the first to formulate the principle of inheritance, the kernel is used in the following way:

$$K(t-\tau) = \frac{c}{(t-\tau)} \qquad (7)$$

Boltzmann kernel application results in the logarithmical increase of the settlement with time (Rabotnov 1977). Under the constant strain the finite expression reflecting the settlement progressing with time equates as follows:

$$S(t) = \ln(t) + c \qquad (8)$$

Data obtained from special vibrostamp experimental tests conducted in compliance with the technique specified in (Ilyichev at al. 1986) validate the expression competence to describe the deformation progress with time on steady-state (exhaustion) phase of creep (see figures 3 & 4).

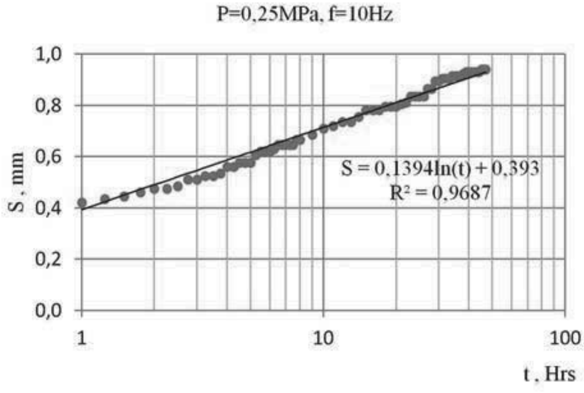

Figure 3. The curve of settlement progress with time a_z = 5μm.

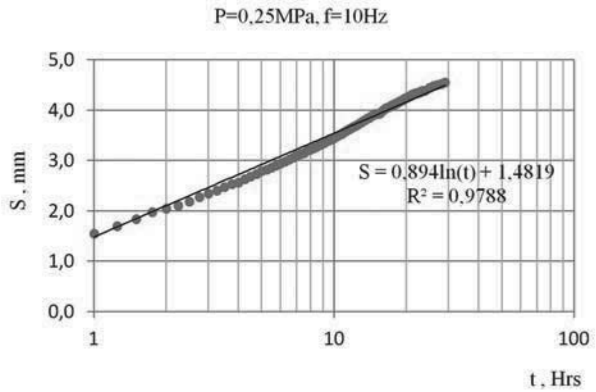

Figure 4. The curve of settlement progress with time a_z = 10μm.

3 CONCLUSIONS

Manifestation of rheological properties of concrete and soil should be taken into account for the three moments of the loading time: t=0; t→∞ and t= tcr. The results of the conducted research show that the system gradually «adapts» to the sustained load, which leads to increase in force in the first loading period, and further – to their decrease (by 20-25%). Consequently, a reserve for the load increase will appear in structures under the sustained load.

Known buildings and structures damage, as well as the machinery dysfunction has proved the importance of the issue under consideration. The research conducted has confirmed the possibility of applying the hereditary creep theory to determine the vibrocreep settlement value. The reliability R2=0.97-0.99 of data approximation with logarithmical function confirms the accuracy of the technique developed.

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