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Some problems of the founding of the powerful turbo- generator sets

Certains problèms confernant l'amenagemént des fondations pour les turbomachines puissantes

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ABSTRACT
The determination procedure of the load bearing capacity of the pile, subjected to the sustained dynamic action, is described. The results of the experimental theoretical investigations, exposed the dependence of the soil basement elasticity coefficients on its anisotropy degree are presented too. The data about the turbo generator set temperature effect on the foundation superstructure deformation are given.

RÉSUMÉ
Description de la méthode de définition de la capacité portante du pilot exposé à un impact dynamique de longue duréé. Presentation des résultats de la recherche théorico-expérimentale, révélant la dépendance des coefficients de l'élasticité de la base au sol par rapport à son degré d'anisotropie. Sont exposées les données concernant l'impact thermique de la turbomachine sur la déformation de la structure superienne de la fondation.

1 INTRODUCTION

The powerful turbo-generator sets transfer the dynamic actions to their foundations. These actions in their turn are transferred to the basement through the foundation.
The current standards (1) make high demands of the turbo-generator sets foundation basements. In particular it is prohibited to use for the turbo-generator sets the basements, produced from the fine and powdered sand of any density. The above mentioned led to the using of the pile foundations and the powerful soil cushions.

2 PILE TEST METHOD FEATURES BY DYNAMIC LOADING

The using of the pile foundation is accompanied by the demand of the determination of the pile load bearing capacity according to the results of its field tests under the sustained dynamic load. The procedure of such tests is stated in (2) and its gist is in the formation and the using of the «load-pile settlement» dependence, which is received experimentally, moreover the last includes the settlement created owing to the sustained vibration besides the statical settlement. Evidently that this procedure of the experimental data processing can not be enough accurate since it is based on the just a second result and does not take into account in the first place the time factor. For the examination of problem about the pile load bearing capacity, subjected to the sustained vibration load action the static dynamic tests of 15 driven reinforced concrete piles C 14-35 beared against the sandy soils were carried out.
The test realization procedure is in accordance with the demands of the Supplement 2 (2); the dynamic stage was carried out on the operating frequency of the low speed turbo-generator set at 25 Hz with the amplitude vertical oscillations of 10 mkm. The experimental data processing was carried out by two ways : according to (2) and according to the ways described below. The test results are given in the table 1.

Table 1. The pile test data by the sustained dynamic loads.

№ of pile	Special value of the limiting resistance, F_u, kN	General dynamic stage time, t, hour.	The stage time to the point of the conditional stabilization reaching: t, hour
Site 1			
C-4	750	70	-
C-6	800	-	-
C-8	1200	70	50
C-10	1000	35	20
C-12	800	85	-
C-16	800	85	-
C-21	1200	100	40
C-21	1400	110	55
C-24	1050	38	-
C-25	900	100	30
Site 2			
C-6	800	106	-
C-8	1100	93	-
C-9	850	66	30-
C-11	1000	78	30
C-27	900	35	-

The averaging values : the special value of the pile limiting resistance Fd =950 kN; the dynamic stage time t = 76 hours; the time to the point of the conditional stabilization reaching of the pile settlement t = 35 hours.
With the experimental data processing according to the method (2), where traditionally it is used the dependence «load– pile settlement» calculated by the formula $(1+\Delta_d/\Delta)^{-1}$ equal to 0,92 (Δ_d; Δ are correspondingly the «dynamic» and static settlements).
In the second case it was examined the dependence of the form $s_p - t^n$, where s_p is a pile settlement, supplementary to the statical pile settlement, t is a dynamical load action time, n is a power index with t. For all the piles the mentioned dependence has a form of the straight line, the inclination of which toward the axis of abscissas is determined by the proportionality coefficient D_p (look fig. 1).

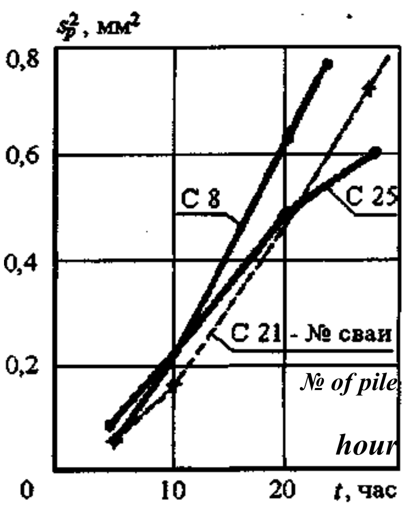

Fig.1. Dependence = S_p^2 - t

D_p is the "pile – soil" system vibrating creep coefficient (mm^2 / hour) calculated by the formula

$$D_p = s_p^{\,2} / t \qquad (1)$$

The value search of the parameter n is illustrated at fig.2. The final sections of all the experimental curves, which affirm the settlement conventional stabilization reaching, have practically the same slope angle toward the axis lgt, equal about $25^0 \approx$ arctg 0,5 that corresponds to the power index with t equal n = 1\2.

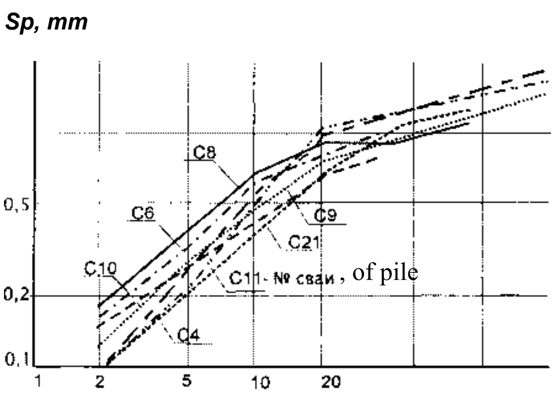

Fig.2. Dependence lgs_p - lgt

The above stated approach permits to offer the following method of the test results processing for the piles with sustained acting loads:

1. By the formula (1) the proportionality coefficient is determined for each tested pile Dp.
2. Then by the formula (2)

$$\bar{s}_p = \sqrt{D_p t_n} \qquad (2)$$

is determined supplementary to the static pile settlement the pile settlement , which has shown for the time t н that is the time between overhauls.

3. Further by the formula (3) it is calculated the coefficient Kp , this is a coefficient of the load pile bearing capacity decrease taking into account the time coefficient

$$k_p \; \frac{1}{1 + \bar{s}_p / S_{u,mt}} \qquad (3)$$

where $S_{u,mt}$ is a limiting median settlement value of the pile foundation of the designed structure (is set by the design organization).

4. And finally the pile load bearing capacity, taking into account the sustained dynamic actions is set up with the aid of the expression

$$F_d = F_u k_p \qquad (4)$$

The results of the experimental data processing by the offered procedure are given in the table 2 (here the coefficients Kp are given for the convenience of the comparison too).

Table 2 .The results of the experimental data processing.

№ of pile	k_F according [2]	D_p, mm^2/hour	K_p according (4)
Site 1			
C-4	1,00	-	-
C-6	1,00	-	-
C-8	0,86	0,035	0,740
C-10	0,91	0,043	0,720
C-12	0,87	-	-
C-16	1,00	-	-
C-21	0,85	0,028	0,760
C-21	0,85	0,036	0,740
C-24	0,95	-	-
C-25	0,90	0,021	0,790
Site 2			
C-6	0,88	-	-
C-8	1,00	-	-
C-9	0,93	0,035	0,740
C-11	0,93	0,033	0,730
C-27	0,89	-	-

The median coefficient of the pile load bearing capacity decreasing is equal k_p= 0,75. Hence, the pile load bearing values, determined by (2) should be approximately at the 20 % more in comparison with the experimental data, that may be a reason of the increased deformation of the turbo- generator set foundation basement.

3 ANISOTHROPIE INFLUENCE ON ELASTICITY CHARACTERISTICS OF BASE SOIL

It is known that the soil elasticity characteristics are very changeable and depend not only on the soil composition and the soil physical properties, but on the genetic peculiarities, the stressed state and other little studied factors too. That is why one can consider that the anisotropy as a genetic peculiarity is present in a number of the natural and artificial basements and influences on the ground elasticity characteristics changing. An anisotropy of the deformation properties means the difference of the deformation modules in the horizontal E_h and vertical E_v directions. The quantitative estimation of the anisotropic basement properties is carried out by the anisotropy coefficient n_a= E_h\ E_v.

The basic results of the experimental theoretical researches permiting to determine the dependence of the soil basement elasticity coefficients on its anisotropic degree are presented in this work (3). It was determined that:

- the influence of the basement deformation properties anisotropy must be considered with the determination of the stiffness coefficients by means of calculations when are lacking the experimental data about the values of these coefficients or about the deformation modulus and they are determined in accordance with the normative documents;

- for the accounting the anisotropy influence on the basement elasticity coefficient the theoretical relationships and tables can be recommended and they are given (3);
- with an insignificant anisotropy ($0,75 > n_a > 1,5$) the using of the coefficient of 0,7 , recommended by the norms (1,2) for the determination of C_x by means of calculations through C_z is legitimate since for the isotropy basement this interdependence is really close to 0,7…0,8;
- with an essential anisotropy ($n_a \geq 1,5$) the relation between the coefficients C_x and C_z may change from 0,4 up 1,15 that requires to consider obligatorily the basement anisotropy, when the coefficient C_x is determined.

The oscillatory system mass influences essentially on the basement dynamic characteristic values. The normative documents recommend to admit this mass equal to the mass of the foundation and the equipment installed on it. The research results show that the more exact correspondence of the experimental and calculated data takes place on considering that together with the foundation the ground mass which surrounds it and has a name as «joined ground mass» takes part in the oscillations.

Consider the evaluation of the basement anisotropy influence on the quantity of the joined ground mass, taking place in the oscillations.

The joined ground mass m_{gr} , taking place in the oscillations together with the foundation is accounted by the coefficient $\beta = (m_{gr} + m_f)/ m_f$, where m_f is a foundation mass and an equipment installed on it. The value m_{gr} depends essentially on the foundation characteristics and also on the basement physical and structural properties. In a number of cases the joined ground mass exceeds the foundation mass twice or three as large. Specifically the anisotropy , determining the speed difference of the elastic waves propagation speeds in the basement may be a cause of the ground volume variation, taking place in the oscillations.

There are found the qualitative changes of the amplitude-frequency dependences of the foundation oscillations on the anisotropic and isotropic basements, which have the equal static stiffness. These changes have the different character for the foundations with the different reduced mass $m_{red} = m_f \ \backslash(pR^3)$, where p is a ground density , R is a radius of the round foundation , which is equidimensional as for the area to the real rectangular foundation.

For the «heavy» foundations with the reduced mass m_{red} = 10…20 the influence of the anisotropy is manifested in general in the reduction of the oscillations resonance amplitude by the 15…25 % and for the «light» foundations m_{red} = 2…5 with the displacement by the 10- 30% of the resonance frequency to the lower frequency area. In addition such displacement is more significant for the «lighter» foundations and with the great difference in the deformation modules in different directions. In the afterresonance zone the basement anisotropy influence practically does not reflect in the oscillations parameters.

The listed noncoincidences , which are an illustration of the basement deformation properties anisotropic influence cannot be taken into consideration and cannot be described within the limits of the Winkler- Foigt model, recommended by the normative documents for the foundation oscillations. However one may use the procedure of O.Ya. Shechter (4), who introduced in this scheme the third parameter – the joined ground mass.

In this statement according to the method of the limiting amplitudes (O.Ya. Shechter) the comparison of the foundations oscillation dependences, received on the anisotropic half-space with the simplest scheme of the dynamic calculation in the form of the system with the single degree of freedom is carried out. As a result the values of the joined ground mass coefficient β were determined for the foundations with the different reduced mass m_{red} and their dependence on the basement deformation properties anisotropic degree was examined. The received data testify about the essential dependence of the coefficient β on the basement anisotropic degree n_a what is shown on the table 3.

Table 3. Value of the joined ground mass coefficient β depending on the n_a anisotropic degree.

m_{red}	n_a				
	0.2	0.5	1.0	2.0	5.0
2	2.52	2.04	1.50	1.99	2.08
5	1.36	1.28	1.19	1.23	1.32
10	1.19	1.16	1.07	1.08	1.16
20	1.15	1.11	1.05	1.07	1.10

The coefficient β rise with the increase of one of the deformation modules is explained by the change of the relationship between the elastic waves speeds propagation in the ground in the different directions.

With the equal area of the foundation surface, contacting with the basement the joined ground mass exercise the relatively greater influence on the «lighter» foundations in the form of the thick plates (the coefficient β increasing is by the 40 – 70 % in comparison with the isotropic case). The realized investigations have shown that such influence becomes essential in that case, when the basement ground deformation modules in the different directions differ between themselves by twice and more as large.

4 INFLUENCE OF TURBO – GENERATOR TEMPERATURE REGIME

The long years observations of the great power turbo – generator sets vibration state have shown that one of the causes, determining the foundation upper structure deformation state is the temperature condition of its vertical load bearing elements.

For the quantitative evaluation of the foundation load bearing elements temperature condition the problems about the foundation columns and walls heating (cooling) both for its height and over the section, depending on the heating time were solving by the methods of the thermal conductivity analytical theory (5). According to (5) in the first case we can examine a column or a wall as the half limited rod with the heat source on the end of rod and in the second case – as the crossing of two unlimited plates, forming the column section.

The performed calculations have shown that the concrete column heating process ends at the distance no more than 1 m from the heating zone. The analogous results are received for the foundation walls too. Hence it follows that the heating for the height of the column and wall principal part occurs through their lateral surfaces. That is why for the quantitative evaluation of the foundation load bearing elements heating process over their section the problem was solved about the unlimited plate heating.

As a result of the performed calculations it has determined that the foundation mass temperature stabilization processes are limply proceeding and short (no more than twenty four hours) oscillations of the air temperature around the foundation cannot influence noticeably on its thermal state. The temperature measurements of the turbo – generator sets mass concrete foundations carried out on the atomic power station of Ukraine, have shown that some elements temperature fields of each foundation are differed essentially. This leads to the uneven local deformations of its upper structure and finally to the line curving of the machine shaft line and to the vibrostate change of the turbo – generator set - foundation – basement (TFB).

Thus it has found that the heat exchanging processes in the elements of the TFB system are limply proceeding. Therefore, the concrete foundations cannot be cause of the turbo-generator set vibrostate change with the short term (during twenty-four hours) changing of the atmosphere temperature around the foundation. If the oscillations in the system change then the causes of this should be found in the machine, the metal of which responds quickly on the temperature changing.

5 CONCLUSION

Performed researches gave the possibility to work out the diagnostic models of the diagnostic complex system in a part of the construction component of the atomic power station power generating units, including a control and a forecast of the foundations vibrostate and the dynamic cracking in a complex with the temperature diagnostics of the foundations vertical load bearing elements and the static deformations diagnostics of some constructive elements.

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