FIGURE 27
Foundations of this building in Zaporozhye showed no additional settlement when flooded with storm water.

erected on weak soils requiring treatment *(Figs. 24, 25, 26, 27)*.

The new method of loess soil consolidation has aroused great interest among the builders not only in the Soviet Union but in other countries as well.

At the Fourth International Congress on Soil Mechanics and Foundation Engineering in London in August 1957, the author made a report on the thermal treatment of settling loess soils, which was then published in the proceedings of this Congress and in a number of technical magazines in other countries.

Foundation Analysis for Machines with Dynamic Loads

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Since 1925, as a result of extensive development of large-scale industrial construction, systematic studies of the dynamics of machine foundations have been carried on in the USSR. These studies were conducted both by experimental and theoretical methods.

A characteristic feature of the experimental work was that it was performed, not in laboratories but directly on construction sites, and data thus obtained were checked by investigating numerous foundations at industrial plants in operation.

These data, combined with the results of fundamental research, enabled us to evolve sufficiently reliable and practical methods of foundation analysis for machines with dynamic loads.

The scope of the present paper precludes the possibility of dwelling on details of the experimental and theoretical research and I will confine myself to a description of the methods of machine foundation analysis which have been established and checked by the practice of many years.

The methods of machine foundation analysis are controlled by specifications evolved by the Foundation and Underground Construction Research Institute with the participation of several research and designing agencies. As far as we know, such specifications applying to the foundations of a large range of machinery exist only in the USSR.

According to the latest edition of the specifications approved by the USSR State Building Board and made mandatory from July 1958, machine foundation analysis includes the check of the following items:

(a) Strength of the foundation soil.
(b) Strength of the foundation structure.
(c) Amplitudes of foundation vibration.

The results of the analysis serve as a check and, whenever necessary, for specifying the principal dimensions, which, however, are chosen in most cases from design considerations (a suitable location of the machine and its secure installation on the foundation).

(a) Foundation Strength Check

This check of foundations for machines with dynamic loads is carried out in the same way as for foundations carrying static loads: the average soil pressure with respect to the base of the foundation exerted by the weight of the machine and of the foundation structure, is compared with the design resistance of the soil under the foundation.

The only difference from static design is the selection of the design resistance of the soil. A dynamic load is taken into account through reducing the design resistance, in some cases according to the formula:

Where R_d is the design resistance of the machine foundation base; R_{st} is the design resistance of the base (bed) according to the standards for static loads; α is the empirical reduction factor, the value of which depends on the type of machinery according to the table below.

$$R_d = dR_{st}$$

Type of Machinery and Equipment	α
Crank shaft machines, rolling and crushing equipment, metal-cutting machine tools	1.0
Turbine-driven sets, electric machines, grinding installations	0.8
Forge hammers	0.4

(b) Foundation Structure Strength Check

1. The check of the strength of a foundation is carried out, whenever necessary, according to the conventional rules of structural mechanics. The relative permanent and temporary loads characteristic of the machine under discussion are introduced into the computations.

The strength check for turbine-driven sets and electric machines, for example, is conducted for the following design loads:

(a) Permanent loads depending on the machine weight (including the weight of the revolving parts), the auxiliary equipment weight and the dead load of the construction elements.

(b) Temporary loads corresponding to the dynamic effect of the machine, the vacuum suction (draft) in the condensor, the moment of short circuit as well as the assembly loads.

2. The temporary design loads corresponding to the dynamic effect of turbine-driven sets and electric machines acting at right angles to the machine shaft are determined, regardless of the capacity, according to the formulas:

$$N_1 = \gamma_1 G_r \text{ and } N_2 = \gamma_2 G_r$$

where N_1 and N_2 are vertical and horizontal design loads respectively

G_r is the weight of the revolving parts for the given foundation element.

γ_1 and γ_2 are the factors accounting for the alternating effect of the loads and selected according to the table below:

Rpm	For Vertical Loads γ_1	For Horizontal Loads γ_2
1500 and more	15.6	2.6
Less than 1500 and down to 500	10.4	2.6
500 and less	5.2	2.6

3. The temporary design loads corresponding to the vacuum suction in the condensor P_t and the short circuit moment, are usually supplied by the manufacturer of the machine. If these data are lacking, the following empirical formulas are sometimes used to determine the above-mentioned loads.

$$P_t = 11F \text{ (in tons)}$$

and

$$M_3 = 4W \text{ (in mm)},$$

where:

F is the area of cross-section of the neck coupling the condensor with the turbine in sq m.

W is the generator capacity in thousands of kw.

4. The forces acting on the foundation elements of turbine-driven sets and electric machines are determined for the following combinations of loads:

(1) Primary combinations of loads consisting of permanent loads, the load from the vacuum of the condensor P_t and of one of the temporary loads N_1 (directed downward) or N_2.

(2) Special combination of loads consisting of the loads of one of the primary combinations and the short-circuit moment.

(c) Foundation Vibration-Amplitude Check

1. To find a sufficiently rigorous solution of the problem of vibrations of massive foundations for machines with dynamic loads we would have to consider a rather complex system consisting of several elastic related bodies. These bodies—the parts of the machine, the foundation block, and the mass of the soil in the foundation base differ considerably from each other in shape, dimensions and elastic properties.

As was suggested by N. P. Pavlyuk (1933), the following substantial simplifications were adopted for the solution of this problem:

(a) The machine and the foundation are regarded as absolutely rigid bodies.

This simplification proves to be completely justified if one takes into consideration that the dimensions of the machine and foundation are small if compared with the dimensions of the effective zone of the base, whereas the values of the elasticity modulus of metal and concrete are hundreds and thousands of times greater than the values of the elastic moduli of sand and clay.

(b) The base of the foundation is assumed to be elastic and void of mass.

This second assumption is more dubious from the theoretical point of view. As was shown by numerous experiments by Barkan, Pavlyuk and other researchers, the estimates based on this assumption yield results which are in good agreement with reality, provided the elastic characteristics of the base are correctly selected. The research carried out by O. Ya. Shechter in 1948 also showed that the neglect of the inertial properties of the soil does not result in any essential distortions in the computations.

Thus, the dynamic analysis of massive foundations may be based on the consideration of the problem of the oscillations of a solid body resting on an elastic base represented by a model of springs.

2. As was pointed out, the correct selection of the elastic characteristics of the foundation base (factors of its rigidity) is one of the most important conditions for obtaining satisfactory results.

As is known, factors of rigidity of the foundation base may be determined by the formulas:

$$K_z = C_z F;\ K_x = C_x F \text{ and } K_y = C_y T$$

where K_z, K_x and K_y are the factors of rigidity of the base for elastic uniform compression, elastic uniform shear and elastic non-uniform compression, respectively.

F and T are the area of the foundation and the moment of inertia of its base with respect to the main axis normal to the plane of movement.

C_z, C_x and C_y are the dimensional factors of proportion for the corresponding types of elastic deformations of the base.

To determine the factors C the method of local deformation was used for a long time. The method was based on the Fuss (Winkler) hypothesis according to which the normal component of specific pressure at any point of the bases is directly proportional to the local elastic deformation at this point.

As was shown by experimental research, the factors are not permanent values and depend, not only on the elastic properties of subsurface, but on other data, and primarily on the shape and size of the foundation base.

The data obtained made it imperative to give up the Fuss hypothesis. Therefore, Prof. Barkan of the Foundation and Underground Construction Institute, suggested in 1934 that the model of a weightless elastic isotropic semi-space should be used for these purposes. On this basis sufficiently simple expressions were obtained for the coefficients C, which are similar to the Schleicher equation for a rigid die.

The new theory corresponds better to reality. However, here too we find some deviations. According to the new theory the coefficients C decrease in inverse proportion to the square root of the area of the foundation. However, according to experimental results, the decrease of C proceeds at a somewhat slower rate. The deviation between theory and experiment increases with the size of the foundation area. Therefore, in design practice it is recommended to utilize theoretical relationships for foundations with a base area F equal to or smaller than 10 square meters; for larger areas the coefficient C is assumed to be constant. As a rule the coefficient C has to be determined by trial load tests of the soil.

3. According to the technical regulations of the Soviet Union the foundation design for oscillations is compulsory only for forge hammers, jaw crushers and crank-shaft machines in the presence of exciting forces of the first harmonics, as well as for electrical machines with less than 1,000 rpm (forced oscillations).

Computations are made for the purpose of comparing the magnitudes of oscillation amplitudes which are expected with the values which are permitted for a given type of machine.

The study and the analysis of the operation of machines in actual practice have made it possible to establish rules for the permissible magnitude of the amplitudes of oscillation. These values are:

(1) For crank-shaft machines—
with less than 200 rpm....0.25 mm
with 200 to 400 rpm......0.20 mm
with more than 400 rpm...0.15 mm

(2) For gyration and jaw crushers ....0.30 mm

(3) For electric machines—
with less than 500 rpm....0.20 mm
with 500 to 750 rpm......0.15 mm
with more than 750 rpm...0.10 mm

(4) For forge hammers—
with saturated sands in the base ....0.80 mm
with other soils...........1.20 mm

4. The practical methods of the determination of the amplitudes of foundation oscillations are based on a well-developed theory of the oscillation of a solid body resting on the elastic base mentioned above. This theory has incorporated certain simplifications and specifications following numerous experiments carried out in the USSR by D. D. Barkan, A. D. Kondin, N. P. Pavlyuk, O. A. Savinov, Y. N. Smoshkov and others.

In this short paper there is no need to set down formulas for foundation analyses of various machines since these formulas have been extensively cited in print.