The diversity of cast-in-place pile construction conditions determined by the hydrogeologic conditions of construction sites, availability of machines and equipment, and degree of supply of labor and material resources for the projects makes necessary the use of different technical schemes for the carrying out of the piling work. For selection of the most effective method of construction of cast-in-place piles it is necessary to compare all the alternatives which are possible under the given construction conditions. However, in the design practice for comparison of alternatives usually not more than three technical schemes are considered, an approach which does not permit taking into account many factors which affect the construction work and, consequently, ensure maximum economic efficiency. Hence, it is necessary to work out a procedure for selecting the pile construction method, taking into account all these factors, which can be divided into two groups: 1) those which depend on the soil conditions (saturation, cohesion, and strength of the soil), and 2) those which depend on the methods of driving the holes, rupturing the soil, constructing the widenings for the pile reinforcement, and placing and compacting the concrete mix.

Analysis of solutions of similar problems in other branches of the construction field [1, 2] show the advisability of the use of economic-mathematical modeling. The basic complexity of the working out of an economic-mathematical model (EMM) lies in the correct selection of the optimality criteria under the condition that the EMM reflect the interrelation of the above-mentioned factors.

To evaluate cast-in-place pile construction alternatives, the writers adopted the following system of criteria: the economic effect (saving) \( E \); the amortized costs on the construction volume \( A_{c,v} \); and the labor-consumption of the executed work \( T_c \). In this case, the EMM can be represented by three special-purpose functions and is of the form:

\[
\begin{align*}
E &= \sum_{\theta=1}^{k} E_{\theta} \rightarrow \text{max} \\
A_{c,v} &= \sum_{i=1}^{n} A_{c,v_i} \rightarrow \text{min}; \\
T_c &= \sum_{i=1}^{n} T_{c,i} \rightarrow \text{min},
\end{align*}
\]

in which \( E_{\theta} \) is the economic effect from the variation of the \( \theta \)-th technical-organizational index; \( k \) is the number of indices affecting the economic efficiency of the construction process; \( A_{c,v_i} \) represents the amortized costs on the volume of executed work of the \( i \)-th operation of the technical process; \( T_{c,i} \) is the labor-consumption of the work of the \( i \)-th operation; and \( n \) is the number of operations in the technical process.

The solution of the formulated multiple-criteria problem was obtained by the method of successive optimization in the following order. Methods of mathematical analysis and discrete programming were applied for optimizing the function of the amortized costs on the volume of executed work (combinatorial problem). Then the alternatives whose labor-consumption did not exceed the normative value were determined. From the normative construction period, the number of parallel flows was established and the economic effect function was optimized.

The adopted investigation procedure is the results of analysis of the most generalized index entering into the EMM—the economic effect $E$—which is the set of effects obtained by changing the technical process parameters. For cast-in-place pile construction, the economic effect is determined as

$$E = (A_{c,vE} - A_{c,vco}) + E_n C (T_n - T_{co}) +$$

$$+ 0.005 k_{oh} C \left(1 - \frac{T_{co}}{T_n}\right) + 0.6 (T_{cs} - T_{c,co}) +$$

$$+ 0.16 (P_s - P_{co}),$$

in which $A_{c,vE}$, $T_{co}$, and $P_s$ are, respectively, the amortized cost on the construction work volume for the pile foundation, the labor-consumption, and the wages for the standard (reference) alternatives; $A_{c,vco}$, $T_{c,co}$, and $P_{co}$ are the same quantities for the compared alternative; $T_{c,co}$ and $T_n$ are the actual and normative periods of execution of the work for construction of the pile foundation; $E_n$ is the normative ratio of effectiveness of the capital investments; $C$ is the budgetary value of the foundation; $k_{oh}$ is the overhead cost rate; 0.005 and 0.6 are coefficients which determine the conditionally constant part of the overhead costs and the conditional overhead cost economy for reduction of the labor-consumption and 1 man-day; and 0.15 is a coefficient which takes into account the overhead cost economy for reduction of the wage amount.

It is evident that the maximum economic effect is ensured when the amortized cost on the work volume, the labor-consumption, and the construction period is minimal.

For investigation of the amortized cost function, the variable quantities used were the work execution rate $V_j$ of the $j$-th equipment and the capacity (power) $N_j$ of the $j$-th equipment. Then the amortized cost equation for the pile construction work is of the form:

$$A_{c,v} = \sum_{j=1}^{m} \left( a_j \frac{N_j}{V_j} + \frac{b_j N_j}{V_j} + \frac{c_j N_j}{V_j} + d_j \right),$$

in which $m$ is the number of machines in the set.

The proposed coefficient $a$ characterizes the amortized cost as a function of the value expression for the piling execution rate under specific conditions. The coefficients $b$ and $c$ characterize the amortized cost as a function of the value expression for the specific energy consumption of the machines used. The difference between these coefficients resides in the fact that $b$ takes into account the use of machines with diesel and gasoline engines, whereas $c$ applies to electric motors. The coefficient $d$ characterizes the conditionally constant part of the amortized costs on the pile construction volume (value expression of cost on equipment transfer, material costs).

The coefficients $a_j$, $b_j$, $c_j$, and $d_j$ are determined from the expressions:

$$a_j = \frac{1}{k_1} \sum_{j=1}^{m} \left[ \frac{k_{dp} k_{ch} k_{m}}{T_{yrj}} k_j + C_{mdj} + k_{offav} \right. $$

$$\times \left( m_{gj} + m_{mg} \right) \frac{Q_j}{k_{etj}};$$

$$b_j = 1.03 (1 + e) k_{ch} \sum_{j=1}^{m} s_j k_{ch} [(k_{Nj} k_{ec} -$$

$$- k_j) k_{ecj} + k_j] Q_j;$$

$$c_j = k_{ch} \frac{m}{k_1} \sum_{j=1}^{m} k_{m} k_{etj} Q_j;$$

$$d_j = k_{ch} \sum_{j=1}^{m} E_j + C_{mt};$$

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