Optimization of the duration of the pioneer construction period

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Abstract. The construction of facilities in hard-to-reach and underdeveloped areas is an extremely difficult task, the solution of which largely depends on the quality and timely development of the construction area. Significant reserves for reducing the territories pioneer duration are in the combination of the pioneer construction and preparatory periods. To this end, on the basis of a generalization of practical experience, a methodology for linking work is proposed, based on the found equations of communication between the scope of work, the intensity of consumption of labor and technical resources, and the duration of work. The options for changing the scope of work: from the minimum size of the work area per team to the full work area for the whole process are examined and the conditions for rational combination of the pioneer construction and preparatory periods are disclosed.

1. Introduction.
At present, the regions of Siberia, the Far East and the Far North are being developed more and more actively [1, 2, 11]. At the same time, most of these territories are covered by taiga or tundra, have impenetrable swamps, or are located in the permafrost zone. Severe climatic conditions turn these territories into hard-to-reach or underdeveloped areas, the construction of buildings and structures in which has its own specific features. This is primarily due to the need to implement a set of measures for life support and preparing the territories for construction before the principal construction period.

As a result, the entire process of construction of objects in hard-to-reach and underdeveloped areas includes three stages - the pioneer, preparatory and principal periods [3, 4, 7].

2. Materials and Methods.
At the stage of the feasibility study or business plan of the future object, it becomes necessary to determine approximate fundamental indicators - the duration of construction and its estimated cost. It is usually not always possible to count on a regulatory framework or analogues, since each object has many specific features that distinguish this object as individual. However, taking into account the interdependence of these indicators, the search for rational engineering solutions is in the field of effective industrialization of construction due to high or full factory readiness of volume units and enlarged assembly units, and due to such organizational and technological factors as the maximum combination of processes of all construction periods [5, 6, 9].

Period Combination Modeling
As follows from the theory and practice of construction [1, 3, 8], the work of the pioneer construction period can be carried out sequentially and in combination.

With a consistent method, the duration of an object construction in hard-to-reach and underdeveloped areas will be

\[ T = T_1 + T_2 + T_3, \]

where \( T \) is the total construction time;

\( T_1 + T_2 + T_3 \) is the duration of the pioneer, preparatory and principal periods of the construction, respectively.

The relationship between the periods of construction can be represented as follows:
where \( t_0, t_2, t_3 \) are time points for the start of the pioneer, preparatory and principal construction periods, respectively.

With the combined production of works, it becomes necessary to stipulate the conditions under which such combination is possible:

- the coordination of the processes of the construction periods provides for the combined execution of work in time by different contractors (teams, sections);
- work in each section of the preparatory period begins after the previous work of the pioneer period is completed in this section, i.e. the working area of the preparatory process is determined by the products of the previous process;
- the size of the division of the pioneer period can have a wide range from the size of the working area per the brigade (link) to the scope of work throughout the facility, which in each case is determined by the magnitude of the construction products;
- the working area is a site of the territory, sufficient in time and spatial parameters for the appropriate number of the performers and ensure the planned labor productivity;
- the minimum staff is characterized by the ability of this group of workers to carry out the corresponding process, and the maximum staff is determined by the ability of this group of workers to occupy the entire working area of the process.

We denote by \( V_1 \) and \( V_2 \) the volumes (laboriousness) of the work of the pioneer and preparatory periods in combination, and by \( R_1 \) and \( R_2 \) - the number of their performers (intensity of consumption of labor or technical resources); \( t_{1,2} \) is the duration of the organizational break between the beginnings of the pioneer and preparatory periods. Then, during time \( t_{1,2} \) at the pioneer period \( R_1 t_{1,2} \) work will be performed, at the preparatory period \( 0 \) work will be performed. After the \( \Delta t \) time, \( R_1 \Delta t \) and \( R_2 \Delta t \) work will be performed at the pioneer and preparatory periods, respectively, i.e. the scope of work at the pioneer period, expressed through the complexity of the work of this period for the preparatory period will be

\[
R_1 t_{1,2} + R_1 \Delta t - R_2 \Delta t \cdot \frac{V_1}{V_2} \geq F_{1,2} R_2
\]

where \( F_{1,2} \) is the scope of work expressed through the complexity of the work of the pioneer period, necessary for performers of the preparatory period.

Here, \( R_2 \Delta t \cdot \frac{V_1}{V_2} \) characterizes the decrease in the scope of work during the time \( \Delta t \) at the pioneer period as a result of the beginning of the preparatory period. Moreover, the above inequality holds for all \( \Delta t \) values that are in the range \( 0 \leq \Delta t \leq T_1 - t_{1,2} \).

The study of expression (3) allows us to establish that the communication equation, determined by the size of the organizational break between the work of the pioneer and preparatory periods, will have the following form

\[
\begin{align*}
\text{at } \Delta t = 0 & : \\
& t_{1,2} = \frac{F_{1,2} R_2}{R_1}, \\
\text{at } \Delta t = T_1 - t_{1,2} & : \\
& t_{1,2} = \frac{F_{1,2} V_2}{V_1} + \frac{V_1}{R_1} - \frac{V_2}{R_2}. \\
\end{align*}
\]

As \( \frac{V_1}{R_1} = T_1 \) and \( \frac{V_2}{R_2} = T_2 \), then, the minimum organizational break between the pioneer and preparatory periods can be determined by the following expressions:

\[
\begin{align*}
& t_{1,2} = \frac{F_{1,2} R_2}{R_1} \text{ at } T_1 < T_2, \\
& t_{1,2} = \frac{F_{1,2} V_2}{V_1} + T_1 - T_2 \text{ at } T_1 > T_2.
\end{align*}
\]
3. Results and discussions

Forms of resource consumption

The need for renewable resources such as power (working personnel, machines and mechanisms, vehicles, formwork systems, etc.) is characterized at each moment in time by the intensity of their consumption, i.e. amount of resources used. Therefore, this parameter is one of the main ones, since it determines the rate of development of an object in time and, therefore, its duration.

When designing, planning and managing construction, the intensity of resource consumption can be represented both as a constant and as a variable value when performing the process [4, 10, 12].

When representing the intensity of resource consumption in the form of a constant value, the relationship between the duration, volume of work and the intensity of their implementation is expressed by the ratio

\[ T = \frac{V}{R} \]  

(7)

where \( T \) is the duration of work, days;
\( V \) is the volume (labor intensity) of work, people·days;
\( R \) is the number of performers (intensity of resource consumption), people.

To express the variable intensity of resource consumption, a bent sequence is used

\[ R = \sum_{j=1}^{n} R_{j-1} \cdot \Psi(t_j - t_{j-1}). \]  

(8)

where \( \Psi(t) \) is the Heaviside function taking the following values:

\[ \Psi(t_j - t_{j-1}) = \begin{cases} 1, & \text{at } t_j \geq t_{j-1} \\ 0, & \text{at } t_j < t_{j-1} \end{cases} \]

In this case, the relationship between the above indicators is as follows:

\[ T = \frac{V - \sum_{j=1}^{n} R_j \Delta t_j}{R_{n+1}} + t_n, \]  

(9)

where \( t_n \) is the process end time;
\( \Delta t_j = t_j - t_{j-1} \).

Thus, the desired value of the intensity of resource consumption is in the range \( \min R \leq \bar{R} \leq \max R \),

where \( \min R \), \( \max R \) is the minimum and maximum value of the technologically permissible intensity of resource consumption, respectively.

Methodology for determining the combination of processes

The methodology provides for the implementation of the work of the pioneer period in conjunction with the organizational and technological parameters with the work of the preparatory period and establishes the technological sequence of work, the degree of their combination with each other in different parts of the developed territory of the future facility, rational methods of organizing the work, the duration and timing of their production.

The linking of processes is advisable in the following sequence.

1. Determination of physical volumes of work and labor costs for their implementation.

   The physical volumes and labor costs are selected from the work schedule, and in its absence, the physical volumes of work are set according to the working documentation and estimates, and labor costs are set according to the relevant federal or territorial budget norms.

2. The choice of methods of organizing work.

   When choosing methods of organizing work, one should proceed from the condition of their maximum mechanization. In cases of manual work, the use of a mechanized tool and small-scale mechanization tools is provided.

3. Determination of the composition and number of working teams.
The composition of working teams is determined in accordance with the accepted method of work production on the recommendations of estimated standards.

4. Determination of the size of the working area with the scope of work for the working team to complete the pioneer period.

The size of the working area is set by the size of the shift scope of the work and should be sufficient to accommodate the working team with all the means of mechanization and devices. It should also take into account the features of the general scheme of the accepted method of work (direction of movement and parking of cars, storage areas, etc.). The size of the division can vary from the working area by one team to the working area for the whole process

\[ F_1 \leq F_1 p_1 \leq V_1, \]

or

\[ 1 \leq p_1 \leq \frac{V_1}{F_1}. \]

where \( p_1 \) is the number of brigades (number of scope of work per brigade);

\( V_1 \) is the complexity (volume) of work for the pioneer period;

\( F_1 \) is the complexity (volume) of work per brigade.

5. Determination of the working area with the scope of work per brigade for the implementation of the preparatory period.

The working zone is established on the site of the territory of the corresponding process of the pioneer period. The volumes of work (construction products) of the pioneer and preparatory periods are measured in the same units. Therefore, the division size is expressed in terms of the pioneer period

\[ F_{1,2} \leq F_{1,2} p_2 \leq V_1, \]

or

\[ 1 \leq p_2 \leq \frac{V_1}{F_{1,2}}. \]

where \( p_2 \) is the number of brigades (number of scope of work per brigade);

\( F_{1,2} \) is the complexity (volume) of the work of the pioneer period, sufficient for the beginning of the preparatory period.

6. Linking the scope of the pioneer and preparatory periods.

Such a link characterizes the formation of construction products as a result of the technological connection of the processes of the pioneer and preparatory periods in a single area. The changing scope of work dictates the limits of the change in the number of working teams:

\[
\begin{align*}
\max p_1 &= \frac{V_1}{F_1}; & \max p_2 &= \frac{V_2}{F_2} = \frac{V_1}{F_{1,2}} \\
\min p_1 &= 1; & \min p_2 &= 1.
\end{align*}
\]

Consequently, the number of workers will be

\[
\begin{align*}
\max R_1 &= \max p_1 R_1^B; & R_1 &= p_1 R_1^B \\
\max R_2 &= \max p_2 R_2^B; & R_2 &= p_2 R_2^B.
\end{align*}
\]

where \( R_1^B, R_2^B \) is the number of workers in the brigade during the implementation of the processes of the pioneer and preparatory periods, respectively.

Thus, it can be accepted that the minimum scope of work corresponds to the location of the brigade, and the maximum one corresponds to the number of brigades occupied by the entire working area of the process. The number of brigades is determined by the size of the full working area of the process divided by the size of the working area of one brigade.

In this regard, taking into account the found values, it is possible to determine the development of object or specialized flows by transforming formulas (6):

\[ \text{at } T_1 < T_2 \]
\[
\begin{align*}
    t_{1,2}^1 &= \frac{F_1 R_1^B}{p_1 R_1^B} \cdot p_2, \quad p_1 \leq p_2 K \\
    t_{1,2}^2 &= \frac{F_2 R_2^B}{KR_1^B}, \quad p_1 \geq p_2 K
\end{align*}
\]

where \( K \) is the ratio of the scope of work in the working areas of the teams \( F_2 \) and \( F_1 \), expressed in uniform units.

At \( T_1 > T_2 \)
\[
t_{1,2} = \frac{F_1 V_2}{V_1} + T_1 - T_2.
\]

Then the duration of the coordinated processes of the pioneer and preparatory periods will be
\[
T_1 = \frac{V_1}{p_1 R_1^B}; \quad T_2 = \frac{V_2}{p_2 R_2^B}.
\]

4. Discussions and conclusions.

Pioneer work in hard-to-reach and underdeveloped areas is classified as labor-intensive and complex and therefore has a fairly high duration. As a rule, work on the preparatory period is commenced after the completion of the pioneer period. At the same time, as the practice of developing a number of Siberian territories shows, it is not necessary to carry out the pioneer and preparatory periods consistently. The reserves for combining these periods can be up to 50\% reduction in their total duration and this is not the limit value.

The basis for combining the pioneer and preparatory periods is the coordination of their processes with each other in time and territory, aimed at the production of specific finished products - parts of a residential village, a site for receiving construction cargo, planning a territory, creating storage facilities, etc. At the same time, the main parameters of managing the process of combining work are the scope of work and the intensity of labor and technical resources consumption.

The scope of work of the pioneer and preparatory periods can vary widely from the size of the work area per brigade to the size of work area of finished construction products. This flexibility of action freedom, together with a regulated intensity of resource consumption, guarantees an effective territory development strategy and ensures a reliable production output.

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