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ORGANIZATION OF CONSTRUCTION PRODUCTION

LECTURE NOTES

(for third-year full-time
foreigner students first (bachelor's) level of higher education
specialty 192 – Construction and Civil engineering)

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INTRODUCTION

This lecture notes are designed to study the discipline «Organization of Construction Production» and are compiled in accordance with the Bachelor's degree programme in (192-Construction and Civil Engineering).

The main subject of the discipline is the study of modern methods of rational Organization, current and operational planning of construction based on system analysis, modelling and use of BIM technology in the design of construction organization.

Interdisciplinary links: the course is based on the knowledge gained in engineering research (geology and geodesy), the basics of labour and environmental protection, building materials, structural mechanics, architecture, project management, economics and technology of construction production.

The programme of the discipline consists of the following content modules:

1. Organizational forms and management structure in construction. Management of construction production.

2. Production models in construction.

3. Design of construction facilities and construction master plans

The purpose of teaching the discipline 'Organization of construction production' is: to study the basics of rational organization of construction, composition and sequence of engineering and production preparation for construction; organization of work performed during the main period of construction; development of projects for the organization of construction taking into account environmental protection; planning of production and economic activities.

The main objectives of the discipline 'Organization of construction production': studying the methods of construction management of all types of work included in the overall complex of construction of buildings and structures; mutual coordination of these works in accordance with the standard construction time; selection of the most optimal methods of work performance and devices for their implementation; determination of the calendar need for workforce, material and technical resources (materials, structures, construction machines, mechanisms, vehicles, etc.) required for construction; development of issues related to environmental protection during construction.

In accordance with the requirements of the bachelor's degree programme, students should

– **know**: methods of technical and professional substantiation of decisions; basics of labour organization; methods of designing production organization for new construction; ways and directions of technical progress in the construction of buildings and structures;

– **be able** to critically comprehend and apply the basic theories, methods and principles of economics and management for the rational organization and management of construction production;

– **have** the skills to organize and manage professional development in the field of architecture and construction.

Construction is one of the main sectors of the national economy that ensures the creation of new, expansion and reconstruction of existing fixed assets. In construction, as in any other sector of the national economy, production efficiency is increasing through the introduction of scientific and technological advances, improved management and planning, organization of construction production and labour, and the introduction of modern construction management technologies into construction production.

The knowledge gained by students in this discipline is important for their further production activities in the specialist in accordance with their qualifications. The organization of production must constantly reflect the requirements of the times, and therefore always includes the search for and implementation of new innovative solutions. The organization of construction production is one of the most progressive types of production activities in the economy.

TOPIC 1 ORGANIZATIONAL FORMS IN CONSTRUCTION

Questions for theoretical training

1.1 Basic terms and definitions.

1.2 Classification of construction enterprises and the main organizational and economic forms of entrepreneurship.

1.3 General provisions on the organization of construction production.

1.1 Basic terms and definitions

Construction (capital construction) is a branch of material production (a branch of the economy, a sector of the economy), the products of which are finished and ready-to-use industrial enterprises, residential buildings, public buildings and structures, etc. objects of production and non-production funds.

The most important task of construction is to ensure the expanded reproduction of the main funds of the branches of material production with the effective use of capital investments, the intensification of construction production and, on this basis, the improvement of the efficiency of social production. Construction is carried out by general construction and assembly organizations that perform construction and assembly work.

Construction production is an interconnected complex of construction and assembly works and processes, the result of which are ready-to-use buildings and structures, or their parts, ready for installation of technological equipment. Construction production is divided into general construction and specialized works.

Organization - (from the French organization, from the middle Latin organize - arrange a slender form):

1) orderliness, coherence, interaction of individual parts of the whole;

2) association of people who jointly implement a program or goal and act on the basis of certain rules and procedures.

Construction management is an interconnected system of preparation for construction, establishment and maintenance of the general order, sequence and timing of work, supply of all types of resources to ensure the efficiency and quality of the construction complex (construction of an industrial enterprise, urban development complex or residential neighbourhood).

Construction management should ensure that all organizational, technical and technological solutions are aimed at achieving the end result - commissioning of facilities with the required quality and on time.

Construction production organization is an interconnected system of preparation for the performance of certain types of work, establishment and maintenance of the general order, sequence and timing of work, supply of all types of resources to ensure the efficiency and quality of certain types of work or construction of a facility.

The organization of construction production ensures the achievement of the end result - commissioning of each facility with the required quality and on time.

1.2 Classification of construction companies and main organizational and economic forms of business

As a rule, construction production involves not only individuals, but also entire teams united in construction enterprises (firms), entering into certain production relations.

In a market economy, construction companies must meet certain requirements:

– have great flexibility in organising and managing construction;

– to accurately meet the contractual term and duration of construction;

– systematically analyse the amount of revenue received from the sale of construction products (works or services) and the costs of their production;

– to control and improve the quality of construction and installation works (CIW);

– to monitor the competitive level of production and introduce advanced achievements of science, engineering and technology into construction production.

The diversity of types and forms of enterprises that exist in Ukraine can be classified according to various criteria: type of activity, forms of ownership and organizational and legal forms.

In accordance with the forms of ownership established by the Legislation of Ukraine,

the following types of enterprises may operate

– a private enterprise based on the ownership of an individual;

– a collective enterprise based on the ownership of the enterprise's labour collective;

– economic partnership;

– an enterprise based on the ownership of an association of citizens;

– a municipal enterprise based on the property of the relevant territorial community;

– a state enterprise based on state ownership, including a state-owned enterprise. The specifics of establishment, liquidation, reorganization, management and operation of a state-owned enterprise are established by Section VIII of this Law.

An individual private enterprise is an enterprise owned by a citizen on the right of ownership or by members of his/her family on the right of common share ownership, unless otherwise provided by an agreement between them.

Construction private enterprises provide a variety of services and, above all, can produce and sell goods that large enterprises are not ready to master and offer for sale.

Among other types of enterprises, both in Ukraine and globally, the most widespread are business partnerships.

Business associations are enterprises, institutions, and organizations established on the basis of an agreement between legal entities and individuals by combining their property and business activities for the purpose of making a profit. In other words, it is a pooling of their capital. Companies are established and operate on the basis of a memorandum of association and a charter, which are the founding documents.

Under current Ukrainian laws, there are five types of business entities:

– joint stock companies;

– limited liability companies;

– additional liability companies;

– general partnerships;

– limited partnerships.

A joint-stock company is a company that has a statutory fund divided into a certain number of shares of equal nominal value and is liable for its obligations only with the company's property.

A share is a security that confirms the shareholder's right to participate in the management of the company, in its profits and in the distribution of the remaining property in the event of liquidation.

Shareholders are liable for the company's obligations only to the extent of the shares they own.

Joint stock companies include:

– an open joint-stock company, whose shares may be distributed by public subscription and sale on stock exchanges;

– a closed joint-stock company, whose shares are distributed among the founders and cannot be distributed by subscription, bought and sold on the stock exchange.

A closed joint-stock company may be reorganised into an open joint-stock company by registering its shares in accordance with the procedure provided for by the securities and stock exchange legislation and amending the company's charter.

A limited liability company is a company that has a statutory fund divided into parts, the amount of which is determined by the constituent documents.

Members of a company are liable to the extent of their contributions.

In cases provided for in the constituent documents, shareholders who have not fully contributed shall be liable for the company's obligations also to the extent of the part of the contribution not made.

A company with additional liability is a company whose authorised capital is divided into parts in the amount determined by the constituent documents. The members of such a company are liable for its debts with their contributions to the authorised capital, and if these amounts are insufficient:

– additionally with their property in a multiple amount equal for all participants to the contribution of each participant.

The maximum amount of liability of participants is provided for in the constituent documents.

A general partnership is a company where all members are engaged in common business activities and are jointly and severally liable for the company's obligations with all their property.

A limited partnership is a company that includes, along with one or more participants who are liable for the company's obligations with all their property, one or more participants whose liability is limited to their contribution to the company's property (contributors).

If two or more limited partners participate in a limited partnership, they are jointly and severally liable for the company's debts.

The classification of enterprises according to their production capacity (size) is the most common. As a rule, all enterprises are divided into three groups:

– small

– medium-sized

– large.

The following indicators are used to assign an enterprise to one of these groups:

– number of employees;

– value of output;

– value of fixed assets.

Large enterprises have a number of advantages due to concentration of production, internal specialisation and cooperation. In particular, they use equipment and technologies for large-scale production, which, as a rule, have much higher economic and technical performance than for small batches.

Small enterprises appear not only as competitors of monopolies, but also as their satellites. In this case, in accordance with an agreement and on the basis of technical documentation developed by large firms, small enterprises produce the component parts required by large firms. This is convenient for both parties: the large firm is relieved of the need to set up a small production facility, and the small enterprise is provided with constant orders and patronage from the large firm.

The structure of an enterprise is the composition and correlation of its internal links: workshops, departments, laboratories and other components that make up a single business entity.

The structure of an enterprise is determined by the following factors:

– size of the enterprise

– area of production;

– the level of technology and specialisation of the enterprise.

There is no stable standard structure. It is constantly being adjusted under the influence of the production and economic situation, scientific and technological progress and socio-economic processes.

At the same time, despite the diversity of structures, all manufacturing enterprises have identical functions, the main ones being the manufacture and sale of products.

Industry affiliation almost always affects the structure of an enterprise and its size to some extent. These two factors are interrelated.

The structure of an enterprise is directly influenced by the industry's production technology. The more complex the technological process, the more diverse and cumbersome the structure of the enterprise will be, and thus its size. In everyday practice, the complexity of a technological process is determined by

– the variety of ways of influencing the objects of work that are necessary to obtain the finished product;

– the number of technological operations to which the product is subjected in the production process;

– the level of ultimate accuracy of technological operations.

One of the most important industry-specific features of an enterprise's structure is the geographical location of its production units.

Distances between structural units and large production areas are typical for companies in the construction industry, railway and water transport, and road and highway facilities. Construction contractors locate facilities in accordance with the customer's request, regardless of any internal structure. Separate construction sites of enterprises operate independently, and the distance between them can be measured in tens or hundreds of kilometers. What they have in common is that there is a single administrative and economic management and maintenance department.

A construction organization often builds identical or similar residential buildings in different districts, tens of kilometers apart. In this case, it is impossible to provide effective operational management of the construction of facilities and the delivery of labour from one construction centre. Therefore, to perform the same type of work, not one, but several construction workshops and sites are set up (according to the number of objects), and the centre provides the sites with the necessary equipment, building materials, technical documentation, as well as forms an order portfolio and settles accounts with consumers of products, suppliers of raw materials and supplies.

Enterprises have the right to voluntarily combine their production, scientific, commercial and other activities, if this does not contradict the antimonopoly legislation of Ukraine.

In accordance with the applicable law, enterprises may unite into:

associations are voluntary contractual unions of enterprises established for the purpose of permanent coordination of economic activities. The association has no right to interfere with the production and commercial activities of any of its members and uses only the powers voluntarily delegated to it;

corporations – contractual associations created on the basis of a combination of industrial, scientific and commercial interests, with delegation of certain powers of centralised regulation of the activities of each of the participants;

consortia – temporary statutory associations of industrial and banking capital to achieve a common goal (implementation of large targeted programmes and projects);

concerns – statutory associations of industrial enterprises, scientific organizations, transport, banks, trade, etc. based on full financial dependence on one or a group of enterprises. Concerns unite large production teams that have significant production capacities and research and design units. They are able to solve problems of strategic importance. This is a single production complex created according to the research-design-development-distribution scheme. As a rule, a concern has its own commercial bank with branches across the country;

intersectoral state associations – differ from a concern in terms of their smaller capacity and greater diversity of economic activities;

syndicates – associations for the sale of products by entrepreneurs of the same region in order to eliminate unjustified competition between them;

joint ventures (JVs) are formed with the participation of representatives of Ukraine and foreign citizens or foreign legal entities. The property of joint ventures joint ventures is formed by way of contributions. The contributions may be made in the form of property of the partners or cash in foreign currency or hryvnia. The terms of business and distribution of profits between the participants are set out in the agreement;

cartels are agreements between enterprises in the same region on prices for products and services, on the distribution of sales markets, shares in total production, etc;

industrial and financial groups (IFGs) are associations of industrial, banking, insurance and trade capital, as well as the intellectual potential of enterprises and organizations;

holdings – a corporation, a company, a parent company that manages or controls the activities of other enterprises and companies. In foreign practice, a holding company holds a general position due to the ownership of a stake in the enterprises and companies it controls. At the same time, the holding company itself cannot have any property production potential and cannot engage in production activities.

The main purpose of establishing the above associations is to jointly solve scientific, technical, industrial, economic, social and other problems.

1.3 General provisions on the organization of construction production

The organization of construction production should ensure that organizational, technical and technological solutions and measures are focused on fulfilling obligations under contracts for the construction of facilities (putting them into operation with the required quality and within the agreed timeframe), while observing the production, economic, economic and other interests of construction participants.

The execution of works at the facilities should be preceded by a set of measures and works on preparation of construction production, which ensures the possibility of construction in accordance with the terms of the contract and the interconnected activities of all its participants. Preparation of construction production includes general organizational and technical preparation, preparation for the construction of the facility, preparation of the construction organization and preparation for the production of civil engineering and construction works. Preparation of production to the extent necessary for the start of construction works at the facility (start-up complex) and their deployment with the required intensity should be completed before the start of its construction.

The facility should be constructed on the basis of pre-developed solutions for the organization of construction and technology of work performance, which should be reflected in the design and technological documentation (DTC). This documentation is an integral part of the construction documentation, along with design and estimate documentation and working drawings. It includes:

1) a construction management project (CMP);

2) design for the production of works (DPW).

The composition and content of the EPD required to carry out work at the facility is set out in the construction contract, depending on the type of construction, the complexity of the facility, the forms of interaction between the construction participants, etc. Construction production should be organised with the rational use of technological specialization of organizations and units in the performance of certain types of construction and engineering works, provision of certain types of services or construction of certain types of facilities. If necessary, combined organizational forms of management based on a rational combination of industrial and construction production should be used, taking into account the production diversity and differences in ownership of construction participants, their organizational and economic independence, and the dominance of horizontal market-type relations.

The coordinated performance of a complex of works at each facility by all participants in its construction should be ensured on the basis of coordination of their activities by the general contractor, whose decisions on issues related to the fulfilment of obligations under the contract are binding on all participants, regardless of their departmental affiliation, organizational and economic structure and forms of ownership.

When organizing construction production, the following should be ensured.

– rational methods of organizing construction and engineering works that ensure compliance with the terms of construction contracts and are consistent with the production capabilities and interests of contractors (with sufficient volumes and technical and economic feasibility - mainly streaming);

– rational technological sequence of works, technically, economically and technologically justified combination of works; complete provision of each organizational and technological module (building, structure, unit, site, section, floor, tier, space-planning element, room, etc.) with material and technical resources within the timeframe that ensures the performance of works in accordance with the calendar plans and schedules;

– if technically and economically feasible, the construction of buildings, structures and their parts using industrial methods on the basis of prefabricated structures, products, materials, equipment and blocks of increased factory readiness, as well as the consolidated assembly of structures at the construction site before their installation in the design position;

– performing seasonal works, including certain types of preparatory works, in the most favorable time of the year (unless otherwise dictated by the customer's requirements);

– use of modern information technologies, computer facilities and information exchange in solving information tasks of construction production - its preparation, development of the project design, planning and management, provision of all types of resources, accounting, etc;

– working conditions, sanitary and medical services for employees in accordance with applicable sanitary standards;

– Strict compliance with labour protection and safety rules in accordance with the Law of Ukraine "On Labour Protection", fire safety in accordance with the Law of Ukraine "On Fire Safety" and the Fire Safety Rules in Ukraine;

– compliance with environmental protection requirements and agreed conditions of work on the existing urban development sites.

Before starting construction works at the facility, the client is obliged to obtain a permit from the State Architectural and Construction Control (SACC), transfer the construction site and duly executed documents necessary for its full use to the contractor.

The main works on the construction of the facility or its part are allowed to be started only after the site (route) for its construction has been allocated in kind, the necessary construction site fences (security, protective or signalling) have been erected and a geodetic base has been created. Prior to the start of construction of buildings and structures, it is necessary to cut the vegetative soil layer, store it in specially designated places for further use for land reclamation, vertical layout of the construction site, drainage works, construction of permanent and temporary intra-site roads, access roads and engineering networks (sewerage, water, heat, power supply, etc.) required for the construction period and provided for in the construction management projects and projects for the production of works, construction support, etc.

In cases where the construction site is located in an area exposed to adverse natural and man-made phenomena and geological processes (mudflows, avalanches, slides, landslides, waterlogging, flooding, subsidence, areas that are being mined, etc.), after creating a geodetic base, prior to the start of on-site preparatory works, special projects* shall be executed (*=*Hereinafter, the term "project" means design and estimate documentation developed for a specific facility in accordance with the requirements of the DBN on the procedure for the development, approval and approval of design documentation for construction*) priority measures and works to protect the territory from these processes.

The completion of off-site and on-site preparatory works to the extent that they ensure the construction of the facility or its stage should be confirmed by an act drawn up by the client and the general contractor with the participation of subcontractors who performed the preparatory works, the trade union committee of the general contractor and representatives of the territorial bodies of the State Supervision of Labour Protection.

In the construction of large facilities, it is recommended that construction and installation work be carried out in start-up complexes or construction phases, the composition and sequence of which are set out in the contract.

The construction of large enterprises, where interconnected technological units can be allocated, should be organised mainly by the nodal method, whereby the completion of construction and engineering works at individual units creates their technical readiness, which allows for autonomous commissioning and testing of units, mechanisms and devices, regardless of the readiness of the facility as a whole. In this case, the construction schedule, delivery of equipment and structures, the need for materials and their complete delivery to the construction site, provision of labour resources and mechanisation should be considered in the construction management projects in the context of the selected units.

If technically and economically feasible, the construction of typical and repeated buildings, structures and their parts (boiler houses, compressor and pumping stations, transformer substations, transport galleries, built-in premises of industrial buildings, etc.), as well as the installation of technological lines, units, installations and engineering equipment, can be carried out using the kit-block method - with the aggregation of equipment and structures into blocks at supplier plants, prefabrication enterprises or construction industry bases. In this case, the organization of construction production should include the manufacture and delivery of sets of blocks to the construction site, their consolidated assembly and the construction of the facility in accordance with the design and estimate documentation.

The construction management project shall include the necessary feasibility studies, as well as the organization of manufacturing, testing and delivery of blocks to the place of their installation in the design position. The supply of blocks should ensure that the facility can be constructed in the designed technological sequence and within the required timeframe.

In the construction of linear facilities (transport, communication, land reclamation systems, power lines, etc.), as well as when it is necessary to perform work at a considerable distance from the permanent location of construction organizations, it is advisable to use mobile construction units equipped with vehicles, mobile mechanical installations and power supply devices, as well as mobile (inventory) buildings for construction needs, in accordance with the profile of the work.

In necessary cases, if technically and economically feasible, it is allowed to use the shift method of construction organization in such situations, which involves performing work on site by regularly changing units.

For works that require specialised equipment and appropriately trained personnel (artificial chemical, cryogenic and thermal consolidation of weak soils, trenchless laying of underground utilities, installation of high-rise structures, in particular, tower-type structures, application of chemical and heat-resistant coatings, etc.), specialised construction organizations licensed to perform the relevant type of work should be engaged. When constructing facilities on urban development sites, the existing conditions of work should be agreed in accordance with the established procedure with *the relevant state supervisory authorities, local administration and operating organizations*. This shall include:

– the allocation of hazardous areas, boundaries and axes of underground structures and communications;

– transport and pedestrian traffic schemes to ensure safe access and approach to existing enterprises, buildings and structures;

– firebreaks; measures to prevent pollution of the territory, water and air basins, as well as protection against noise, vibration and other harmful and dangerous effects;

– If necessary, resettlement of residents from houses adjacent to the construction site.

Facilities must be constructed in compliance with *building codes, rules and* *standards*, and complex and unique facilities must be constructed in compliance with *special instructions and project specifications*. The use *of international standards* should be specified in the contract.

The organization of construction production must be guided by the applicable regulatory documents:

– contractual relations in capital construction;

– composition, completeness and rules for the design, construction and estimate documentation, as well as providing it to contractors in accordance with the profile of their work;

– provisions on the author's supervision of design organizations over the construction of enterprises, buildings and structures;

– conditions for the production of civil and structural engineering works at the site, the procedure and rules for their execution and acceptance, and the arrangement of workplaces;

– composition of works and standards of resource consumption for their performance;

– terms of delivery of equipment for installation;

– duration of construction of facilities;

– commissioning of completed facilities;

– labour protection, safety, fire safety;

– environmental protection;

– licensing of investment activity participants;

– certification of construction products.

Questions for self-examination:

1. Define the term "Construction (capital construction)".
2. What is "Construction production"?
3. What does the term "Construction management" mean?
4. What does the term "Organization of construction production" mean?
5. What is "Planning of construction production"?

6. State and private forms of ownership of construction enterprises (firms).

7. Classification of construction enterprises.

8. Give us a definition: Joint-stock and non-stock construction organizations (firms).

TOPIC 2 MANAGEMENT OF CONSTRUCTION PRODUCTION

Questions for theoretical preparation

2.1 Functions of construction management.

2.2 Methods and principles of construction management.

2.3 Organizational structure and forms of capital construction

2.4 Construction organizations

2.5 Functions of operational and dispatch management.

2.1 Functions of construction management

Plan – a set of tasks united by a common goal that must be completed in a certain sequence and within a set time frame.

Planning is a management function that represents the process of developing plans, including determining the performance indicators of organizations under resource and time constraints.

Planning of construction production is a management function focused on the formation of a plan for the activities of a construction organization in the planning period to ensure continuous, uniform and intensive work at construction sites. With the transition to the market, the importance of planning (especially centralized planning) of construction production has sharply decreased.

Management is the process of purposeful action by a management subsystem or management body on a management system or management object to ensure its effective functioning and development.

Construction management is the process of the management subsystem's impact on the construction organization's employees, control and regulation to ensure the effective achievement of the goal (maximising profits, fulfilling the production programme, timely commissioning of the facility, etc.)

An effect is the result of an activity and the consequence of any cause, that meets the goal. There are economic, social, production, scientific, etc. effects.

Efficiency is the effectiveness that characterizes the degree of use of resources intended to achieve the goal and the analysis of the ratio of results obtained and costs incurred.

Construction production management should ensure interconnected and effective activities of construction participants to implement the production programme (including obligations under each contract) and decisions on the organization of construction and performance of works.

The content of management is the development of current tasks and their communication to direct performers, feedback and corrective actions.

Management can be presented as a process of analysis, planning, organization, coordination, motivation, regulation, accounting and control necessary to achieve the goal in the most efficient way. According to the famous management researcher P. Drucker, the activities of enterprises in a market economy should be efficient and effective. In this case, efficiency is the result of "doing the right and necessary things", and effectiveness is the result of "doing these things correctly". Efficiency is achieved primarily by a properly organised management process that combines the interdependent functions of analysis, planning, organization, coordination, motivation, regulation, accounting and control, with planning being the priority. Each of these functions combines management activities of a certain focus.

The first function is ***analysis***. Analysis is the study of economic processes that took place at the enterprise in the past, the conditions of the external environment in the present, and establishes trends in the development of the enterprise, threats and opportunities, as well as problems that need to be solved.

The second function is planning. Its tasks are to find answers to the following questions:

– what is the current state of the enterprise in the current environment?

– in which direction the company should move in its development under the current conditions;

– how to implement the tasks in the most efficient way.

The third function is organization. It is primarily responsible for forming the structure of the enterprise based on the tasks it faces and the distribution of powers and responsibilities between departments. In addition, this function addresses issues of organising material supplies, recruiting labour, etc.

The fourth function is coordination, which is aimed at coordinating various external systems in relation to the system in question.

The fifth function is motivation, i.e. activities aimed at activating (interest) employees of enterprises in the unconditional fulfilment of targets and constant search for reserves to improve performance. Managers are constantly striving to find a balance of interests of all parties involved in the production process and redistribution of profits.

The sixth function is regulation. This function is related to current management and is aimed at maintaining the state of the planned process and correcting deviations within the system.

The seventh function is accounting. It consists in obtaining and recording in a quantitative form the results of the state of the object and resources at any time of the system's operation.

The eighth function is ***control***. Control is understood as a management activity aimed at qualitative and quantitative assessment and accounting of performance results. In the overall management process, control acts as an element of feedback, as its data is used to adjust previously made decisions.

The production management cycle can be represented as follows (see Figure 1.2).

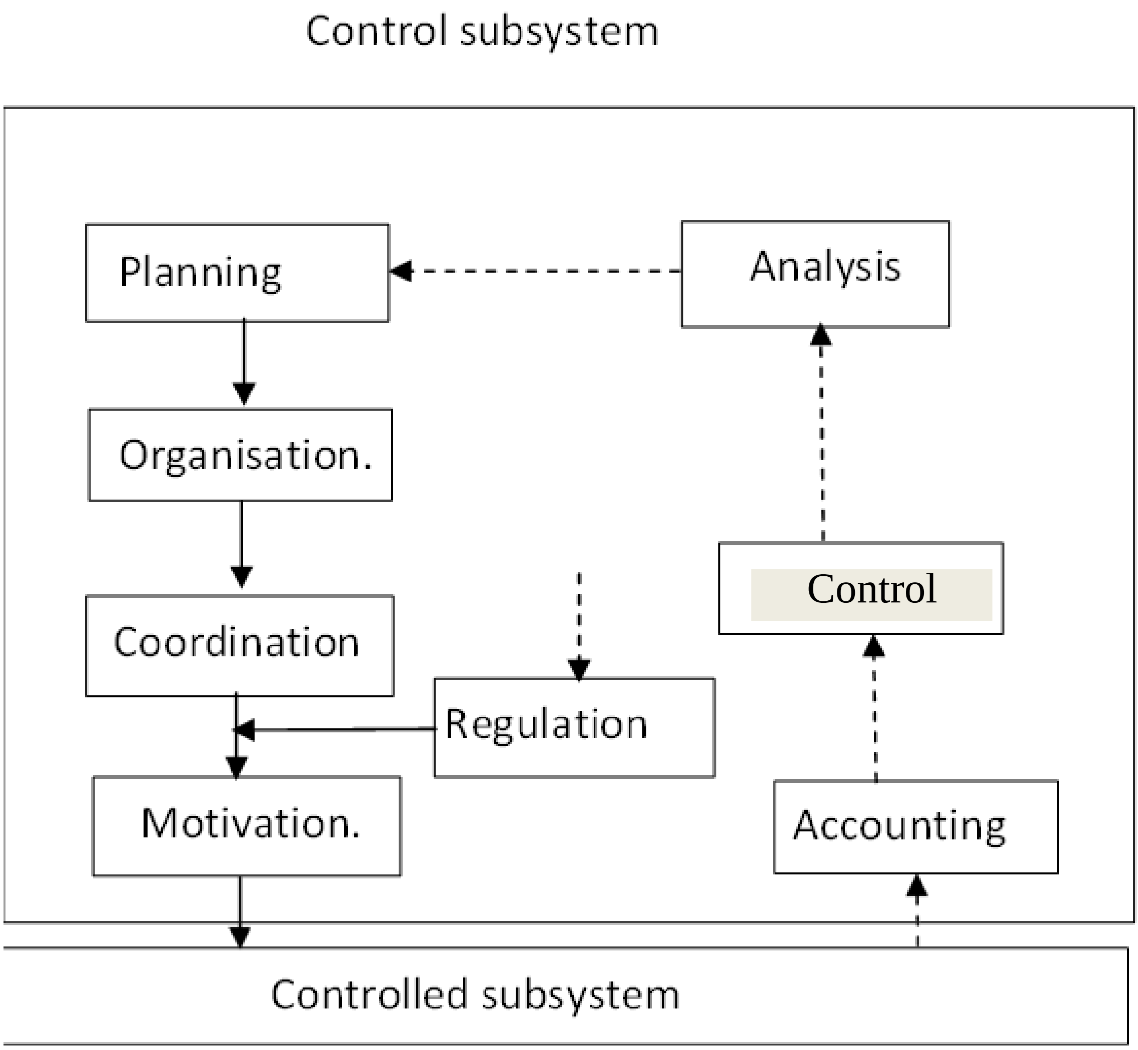


Figure 2.1 – Management cycle

Having revealed the content of the management functions, we came to the understanding that the previously stated statement about the priority of the planning function over other management functions is objective because it is planning that determines the purpose and objectives of implementing these functions based on the development goals of the enterprise. G. Mescon pointed out that «planning - is an umbrella under which all management functions are hidden». Thus, the success of management activities and their efficiency largely depend on the level of planning.

At the same time, it should be emphasised that all management functions are organically interdependent. The efficiency of planning in general depends on the successful implementation of each of them. For example, creating an optimal structure of an enterprise is impossible without a clear strategy (plan) for its development, as different tasks require an appropriate production structure. In turn, the effectiveness of planning largely depends on the efficient organization of work at all levels, and this is a matter of organizational function.

Planning and control are particularly closely linked as two of the main management functions. Although control is subordinate to planning, without proper control, it is impossible to organise planning as a continuous process, since it requires constant comparison (control) of the achieved results with the planned indicators. In the process of control, information is obtained that characterises the state of the company's economy and deviations of actual indicators from the planned ones are found.

Elimination of the identified deviations ensures "self-regulation" of the system. Accounting and analysis of the achieved results complete the management decision-making cycle and prepare information for a new cycle of the planning process.

Formation and specification of tasks for executors and development of decisions on significant corrective actions are the subject of preparation of construction production and formation of documentation on the organization of construction and execution of works. The current coordination of the activities of construction participants to ensure that they perform work in accordance with plans and schedules, the current control over the performance of construction and installation works and their resource provision, their constant accounting and regulation are the tasks of current operational management. It is recommended to carry it out through the dispatching service.

2. 2 Methods and principles of construction production management

There are the following methods of construction production management:

– organizational management methods;

– economic methods of management;

– administrative methods of management;

– social methods.

Organizational management methods include methods and means of organizational influence (action) on labour collectives. The tasks of these management methods include the development of provisions that determine the composition of organizational and preparatory measures and methods of their implementation. In this sense, they are equivalent to the function of the organization. Organizational methods are in the form of structural transformation, standardisation and regulation. Structural transformations include the development and periodic review of the structure of construction organizations and the hierarchical structure of higher management bodies. These methods include establishing the scope of authority of managers of a certain rank, their legal status and the relationship between line and functional units in the management apparatus. As a result of rationing, the consumption of materials and energy resources per unit of work is established: time and output standards; headcount standards, controllability standards; the ratio of categories of different types of employees; working hours and holidays. The effectiveness of organizational norming depends on its combination with material and moral incentives, as well as the application of appropriate sanctions for violations of the norms.

Regulation is the influence on the activities of labour collectives and individual employees through organizational regulations, resolutions, instructions and rules, administrative acts that are binding for a long time. Regulations clarify the boundaries of the activities of various organizations in the production process, establish relationships between them, establish the regime of the production process in general and construction and installation work, rules governing the activities of teams and individual officials (for example, regulations on the foreman, on the manufacturer of work, on departments of the construction company); staffing lists and job descriptions (functions, responsibilities, powers, relationships and accountability) are drawn up. The instructions may be detailed to varying degrees. However, attempts to create as detailed instructions as possible should be recognised as harmful. They are especially harmful when there is an unreasonable lack of trust in the business and moral qualities of subordinates. Restricting the initiative of subordinates deprives them of job satisfaction, promotes redundancy, excessive formalism and bureaucracy.

Economic methods of management are central to the intensification of production activities of labour collectives of construction companies. They are ways of acting based on objective economic laws that stimulate people's interest in achieving the final results of the production and economic activities of construction organizations. Economic methods of management are implemented through self-sufficiency, the main features of which are the achievement of production results with the lowest possible expenditure of labour, material, technical and financial resources, subject to fulfilment of obligations under the contract with consumers of construction products (customers) to complete construction of facilities within the contractual timeframe and generate a certain amount of income. Self-supporting accounting ensures the participation of each division of the construction organization and each member of the labour collective in the management of the production process, or rather, in self-governance. For this purpose, it is important that each unit has its own targets during the construction period, which allow it to estimate costs for each planning period.

The basis of construction companies' activities under economic management methods is financing and cost recovery at the expense of economic income, i.e. such economic categories as self-financing and self-sufficiency are used. Business income is the main source of labour remuneration and material incentives, as well as the fund for production development and social development of enterprises. The desire to increase income encourages labour collectives to manage economically and use material, labour and financial resources rationally. Of particular importance in the use of economic management methods are the contract price and credit. The price is formed on the basis of the estimated cost, which includes all costs of construction of buildings and structures. It is the contract price, which is based on the estimate and agreed with stakeholders, that is an important economic mechanism for influencing labour collectives in construction, as it ensures reimbursement of costs and generates business income.

Prescriptive management methods are designed to specify all forms of action in the management process. They allow regulating the implementation of plans by eliminating or localising factors that destabilise the production process. Organizational regulations and work plans should be the initial basis for the use of prescriptive management methods. Without these documents, prescriptive methods are limited to solving disparate private issues, with the manager's decisions based mainly on his or her subjective perceptions. Orders can be of a different nature and have varying degrees of categoricality. If it concerns only the ultimate goal, it is a task; if the manager determines the ways to achieve the goals, it is an instructional order (instruction). Orders may contain only tasks or tasks and instructions. In all cases, orders must be clearly formulated. The categorical form of a prescriptive action is an order. In conclusion, it should be noted that organizational and administrative methods of management should not be equated with voluntarism, bureaucracy and bare administration.

Business income is the difference between the contractual price of commercial construction products and the cost of their production. Increasing economic income is possible by reducing unproductive costs, increasing labour productivity, reducing construction time and improving the quality of construction products. Increasing business income requires systematic savings in labour, transport, material and energy costs, as well as a reduction in the cost of maintaining the management apparatus. Therefore, each hryvnia invested in construction should bear a share of the profit. The residual profit after paying tax and interest on the loan is put at the disposal of the workforce. The loan, together with production development funds and deductions from profits, allows construction companies to develop their material and technical base, reconstruct existing facilities and upgrade their technical equipment. This leads to the development of their capacity, which will subsequently be reflected in an increase in the social development fund and, accordingly, investments in housing construction and social facilities for the company's workforce. Thus, economic methods of management ensure that labour collectives are more receptive to increased organization and innovation. Socio-psychological methods of management are associated with the study of social and psychological motives of people's actions. This is done through working conditions or directly on the psyche of employees. These methods are divided into social and psychological.

Social methods include the study of working conditions and their impact on the production activities of a construction company. The main thing here is the social environment, its objective existence and subjective perception. The environment influences the needs of a person and his or her interests. Therefore, the effectiveness of social methods depends on the manager's ability to influence the social environment with the help of social, moral, and material incentives. Social incentives include: improvement of living conditions, promotion, etc.; moral incentives include encouragement in the form of gratitude, awarding a certificate of honour, entry in the Book of Honour, etc. Material incentives include various types of bonuses, valuable gifts, and free or partially paid vouchers.

2.3 Organizational structure and forms of capital construction

The organizational structure of capital construction in Ukraine has been formed over a long period of time, simultaneously with the formation of the structure of the entire system of centralised management, developing and improving, it has undergone numerous changes, while maintaining its focus on compliance with the principle of unity of organizational structures. This unity is reflected in the organizational forms of participation in capital construction by a developer, a construction and installation trust, a mechanisation management (trust), a specialised trust, a design institute, a construction industry enterprise, a transport enterprise, a production and technological equipment management, financing, accounting and control. Relationships between the above organizations were regulated by their functions and certain legislative acts establishing the relationship between all participants in the investment process: investor, customer, developer, contractor (subcontractor), designer, and resource supplier.

An investor is an entity engaged in investment activity that finances the construction of an object using its own or borrowed funds. The investor has the legal rights to fully dispose of the results of investments. He determines the scope of capital investment(s); develops the terms of contracts for the construction of the facility; makes decisions on the organizational forms of construction in order to determine the designer, contractor, supplier; and carries out financial and credit relations with participants in the investment process. An investor may act as a customer, a creditor, a buyer of construction products, and may also act as a developer.

Customer – a legal entity or individual responsible for organising and managing the construction of a facility, starting with the calculation of a feasibility study and ending with the commissioning of the facility or the reaching of the design capacity of the construction facility.

Developer is a legal entity or individual who owns a land plot for a building. Unlike the developer, the customer only uses the land plot for the building on a lease basis.

Contractor (general contractor) is a construction organization that carries out the construction of a facility on the basis of a contract or contractor agreement. The general contractor is responsible to the customer for the construction of the facility in full compliance with the terms of the contract, project, requirements of building codes and regulations, and the agreed cost. The general contractor, with the consent of the client, may subcontract certain works or construction of certain facilities to subcontract construction and installation specialised organizations.

Subcontractor – a construction organization that performs specialised types of work: sanitary and technical, electrical, installation of technological equipment, etc.

Designer – a design or research organization that develops a project for a facility on a contractual basis or under a contract.

Thus, the investment process of creating a facility involves somewhat independent organizations with different objectives to achieve their economic effect. Thus, for the investor and the customer, the main objective is to build the facility and put it into operation, subject to minimising capital investments in the shortest possible time in order to make a profit from putting the facility into operation in the shortest possible time; the main task of the contractor is to maximise the profitability of the work by increasing the cost of construction or by means of technical progress. In order to overcome these contradictions, certain incentives are needed to unite all construction participants to achieve the main goal.

From the above, it follows that in the capital construction system, organizational forms and organizational relations between participants in the investment process are very important for achieving the ultimate goal of construction.

In capital construction, there are the following organizational forms of construction: economic method, contractor method, turnkey construction, and bidding.

The economic method of construction is a method of carrying out work directly by the developer (enterprise or organization) using its own resources and means. In this case, the developer simultaneously acts as a construction manager and a construction worker. To this end, it creates the necessary management and production facilities for the construction period, recruits workers and engages construction equipment on a temporary basis. This method is more often used during the reconstruction or expansion of existing enterprises, construction of small facilities on the territory of existing ones, in rural construction, etc.

The contractor method of construction is a method of conducting work by permanent contractor installation and construction organizations (contractors) that perform work for various customers under contract agreements. Under the contractor agreement, the contractor undertakes to use its own resources and means to construct the facility in accordance with the project and the requirements of applicable construction standards and regulations. The employer is obliged to provide the contractor with a construction site, approved design and estimate documentation and ensure timely financing of construction, supply of technological equipment, acceptance of the constructed facilities and timely payment.

To perform certain works, the contractor has the right to engage other specialised contractors by signing subcontracts with them. In this case, the main (general) contractor is responsible to the client for the performance of all works. This method of construction is the main one.

A more widespread form of construction has recently become the turnkey construction, where the functions of the client are transferred to the general contractor.

In this case, the general contractor assumes full responsibility for the construction of the facility in accordance with the approved project, on time and within the approved estimated cost. This increases the general contractor's interest in more economical use of the estimated cost, as the savings are at its disposal, and simplifies the communication system, which contributes to the speed of decision-making and implementation, and ultimately to the acceleration and reduction of construction costs.

In the international practice of capital construction, designers, contractors and suppliers are selected on a competitive basis through tenders. Bidding, as compared to bilateral contracts, creates conditions for competition between contractors, designers and suppliers and allows the customer to choose the most favourable offers. There are two forms of bidding: closed and open. At closed tenders, the customer invites firms already familiar to him, while at open tenders, everyone is invited to participate in the bidding.

The experience of domestic and foreign construction shows that the organizational forms of construction have a significant impact on improving the efficiency of capital construction.

2.4 Construction organizations

The structure of a medium and large construction organization general construction trust is shown in Fig. 2.2.

The organizational structure of the trust (the type and number of its production units) depends on the volume of construction and engineering works performed and the geographical dispersion of construction projects.

In general, the trust includes construction and installation departments, construction sites, production and technological equipment departments, and various auxiliary facilities. Large trusts also include construction machinery fleets, motor depots, and manufacturing enterprises.

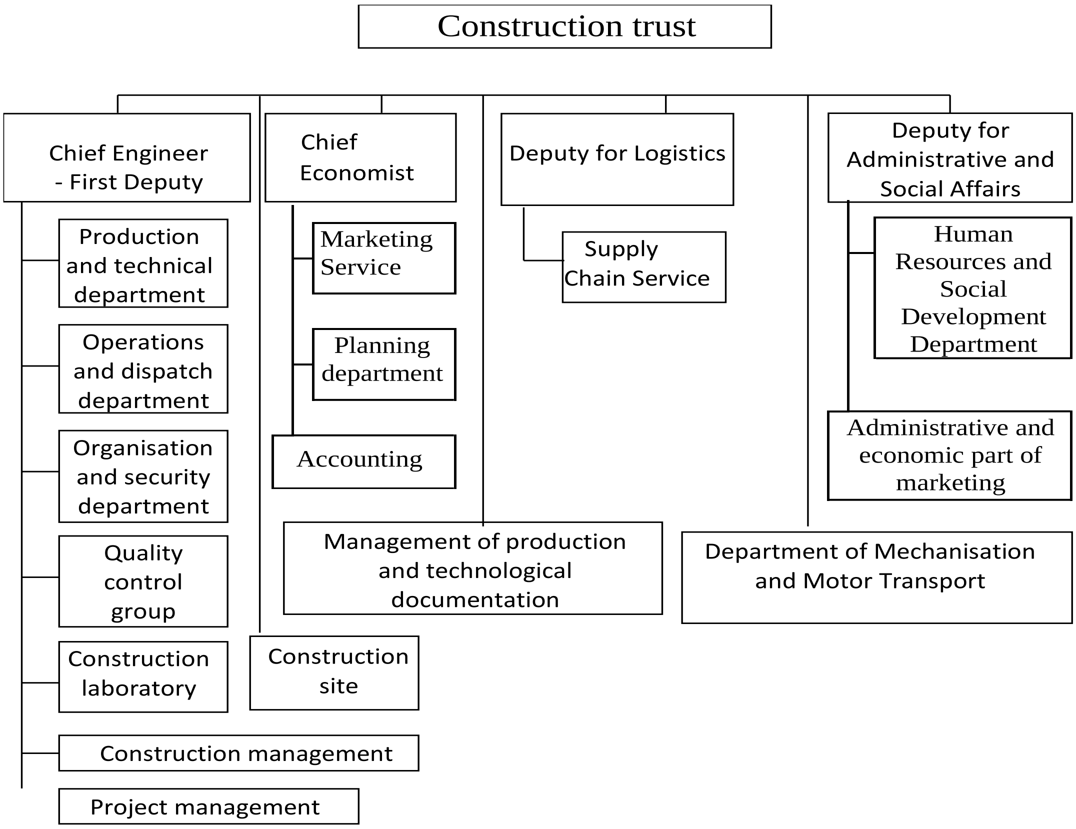


Figure 2.2 – Typical governance structure of a construction trust

The structure of the management apparatus of a trust (and other construction organizations) should be understood as the composition of the levels and links of management, their interconnection and subordination.

Modern organizational structures of trusts have many modifications. The trust is headed by a manager who is responsible for the results of production and business activities.

Depending on the scope of the trust's work, the manager may have 1-3 deputies in addition to the first deputy chief engineer.

The chief engineer is responsible for the technical policy and proper organization of construction production, as well as for the implementation of scientific and technological progress.

The deputy managers are responsible for logistics, economic operations and social and welfare support for employees. The trust's departments, by implementing the relevant management functions, organise work to create conditions for the fulfilment of construction production tasks.

The management of small construction organizations is based on a combination of the principles of sole authority and self-management of the workforce. The sole authority is based on the fact that the organization is managed by a director appointed by its founder. A contract is concluded with the director, which defines his or her rights, duties and responsibilities, as well as the terms of financial support. The director of a small organization approves the staff and determines the number of employees, establishes the system, remuneration and other types of employee income. He or she independently resolves all issues related to the organization's activities, disposes of its property and funds, concludes contracts, opens bank accounts, takes measures for material supply and other issues to ensure the organization's operations.

An exemplary management structure of a small construction organization is shown in Fig. 2.3.

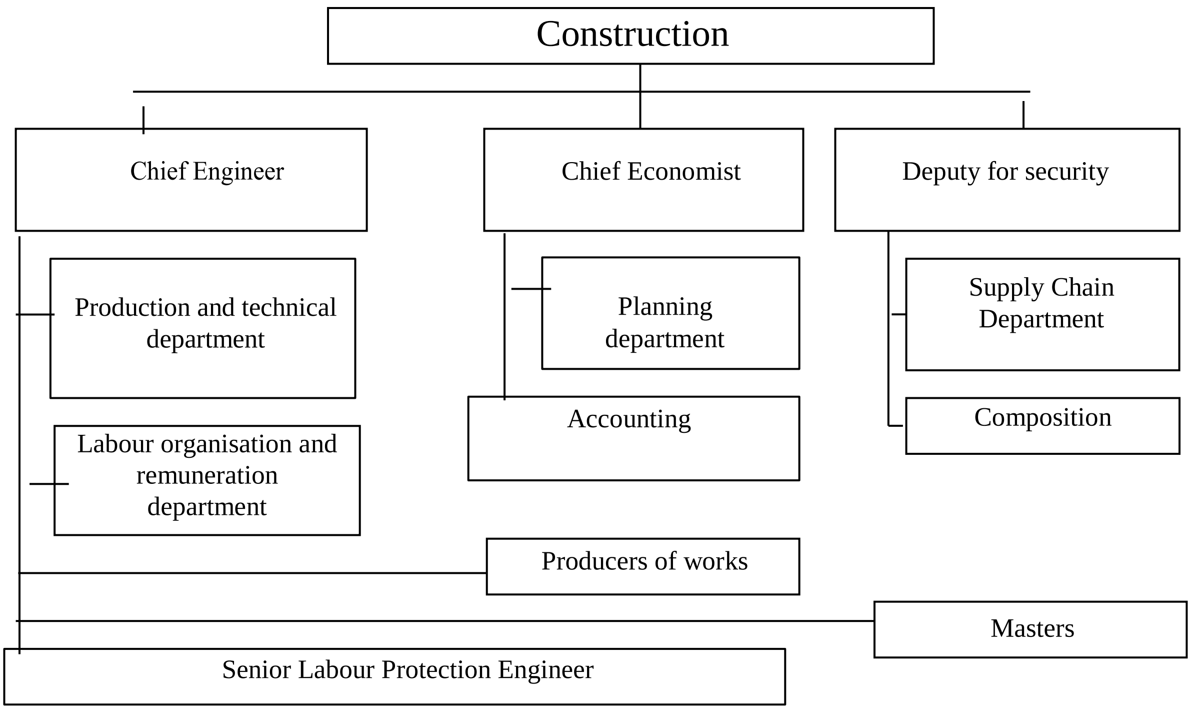


Figure 2.3 – Construction management structure

The self-governing body is the general meeting that elects the board (council).

The organizational management structure of a small construction organization with a relatively small capacity, which includes only the sites of the work producers, is based on a simplified scheme (Fig. 2.4). With a small number of employees, the director's office has only a chief accountant (Fig. 2.5).

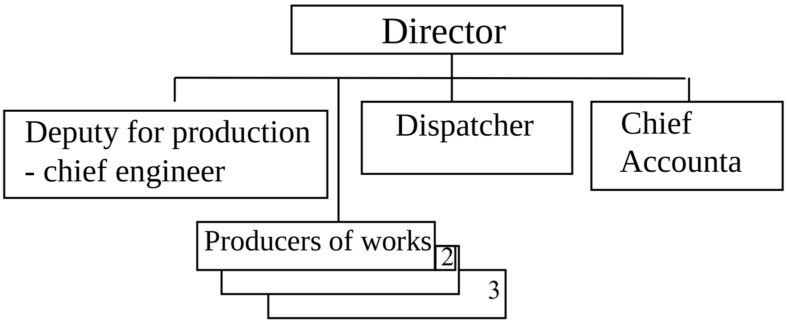


Figure 2.4 – Structure of small construction companies

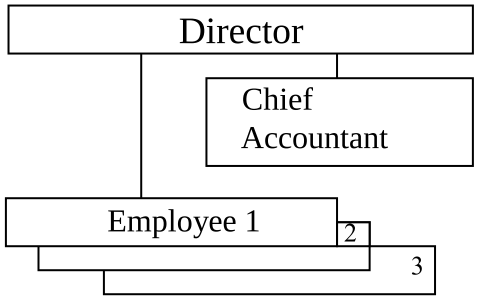


Figure 2.5 – Structure of a small construction firm

In cooperatives, the general meeting of members elects a management board, a chairman and an audit committee to manage the day-to-day operations.

The chairman of the cooperative is the chairman of the board. The management board of a cooperative usually includes the heads of the main structural units. The management board is responsible for organizational, production, economic, financial and social activities.

The chairman of the board ensures the implementation of the decisions of the general meeting, the statutory objectives of the cooperative, and the internal regulations, and manages the activities of the structural units (sections) of the cooperative.

Small organizations and cooperatives, without sacrificing their economic independence and the rights of a legal entity, may join construction and production associations (consortia, concerns) and business associations that provide information, legal and commercial services to their members.

The general meeting of the organizations that are members of the association sets the amount of share and membership fees, approves the programme of activities, annual report, balance sheet and staff, elects the chairman, deputy chairman, members of the council and members of the audit committee.

The Board is a governing body. It manages the current activities of the association and its representative offices, disposes of the property and funds of the association, and performs production, financial, economic, personnel and other functions.

The association has an independent balance sheet and a current account in credit institutions (banks).

Any construction organization, regardless of ownership, must obtain a licence (a document authorising it to carry out a certain type of activity) from the territorial licensing centres.

Under market conditions, the number of construction organizations has increased dramatically and as of the beginning of 1998 stood at about 160,000, including 140,000 small organizations.

In the former USSR in 1990 there were about 4 thousand trusts and 32 thousand primary construction organizations.

In the United States, according to the 1987 census, the total number of construction firms was 19046 thousand units (for comparison, in 1982 there were 1390 thousand units, and in 1977 – 1200 thousand units). At the same time, small construction firms accounted for 71% in 1977, but performed only 11% of the total volume of work. Every year, tens of thousands of such firms appear and cease to exist.

2.5 Functions of the operational dispatching service

The dispatch service performs the following functions of operational dispatch management:

– collecting, transmitting, processing and analysing operational information on the progress of construction and installation works received from organizations and departments, as well as information on deviations from the work projects;

– control over compliance with the technological sequence and regulation of construction and installation works in accordance with the approved schedules production of works, provision of the facilities under construction with material and labour resources, means of mechanisation and transport;

– ensuring constant interaction between general construction, specialised and other organizations and departments involved in construction;

– transfer of information to the management of the construction company or to the control centre of a superior organization in the prescribed form and volume;

– passing on operational orders of the management to contractors and monitoring their implementation.

In the course of reconstruction and technical re-equipment of existing enterprises, it is recommended to create joint dispatching services of the construction organization and the enterprise management, which should provide, in addition to the above, the following additional functions:

– operational management of works to ensure coordinated actions of construction and operational personnel;

– regulation of joint use of transport communications, engineering networks, lifting and other equipment of the enterprise by construction and operational personnel;

– ensuring interaction between general construction, specialised and operational organizations and departments during construction and installation works in parallel with the operation of the enterprise being reconstructed.

In areas where large industrial complexes are being built and residential areas are being developed, a unified dispatch service may be established by mutual agreement of the construction participants.

The effective functioning of the complex of management tasks of the construction industry is ensured by means of its informatisation. A working tool of informatisation is a system of automated workstations (AWS) focused on information support for decision-making at all stages of construction production - during its preparation, development of the project design, management of work performance and provision of all types of resources.

Information, software and technical support for informatisation should be constantly updated and developed to maintain them at the level of current information needs of the industry, its organizations and enterprises, as well as in connection with the development of technical means (computers, communications, office equipment, etc.) and computer information technologies.

Questions for self-examination:

1. Define the term "construction management".

2. Give the stages of development of the science of organization and management in industry.

3. Indicate the stages of development of the organization of stream construction.

4. Classification of construction organizations.

5. Management structure of construction organizations (firms),

6. Functions of operational and dispatch management.

TOPIC 3 MARKETING IN THE ACTIVITIES OF A CONSTRUCTION ORGANIZATION

Questions for theoretical preparation

3.1 The modern concept of marketing in project management

3.2 Marketing research

3.3 Formation of the project marketing concept

3.4 Project marketing programme

3.5 Project marketing budget

3.6 Implementation of project marketing

3.7 Managing marketing within project management

3.1 The modern concept of marketing in project management

In terms of project management, marketing can be viewed in two ways. The first aspect reveals the internal content of project marketing and is the structure of marketing activities regardless of the time duration of the project. This aspect emphasises that at any stage of the project life cycle, marketing is present in its entirety, without changing its internal content.

The second aspect reflects the place of marketing in the project in terms of the temporal structure of the project, i.e. its life cycle. Despite the fact that marketing activities are present at every stage of the project, the importance, scope and content of work at different phases of the project are different.

Conventionally, the first aspect can be defined as the vertical (substantive) structure of project marketing, and the second as the horizontal (temporal) structure of marketing.

Usually, the entire project marketing mix can be divided into 6 components:

" Marketing research;

" Development of a marketing strategy;

" Formation of the marketing concept;

" Project marketing programme;

" Project marketing budget;

" Implementation of project marketing activities.

3.2 Marketing research

Marketing research is usually understood as the activity of searching for, collecting and preliminary analytical processing of information that is relevant to the market success (performance) of a project. Marketing research is a basic activity that provides all subsequent marketing activities with the necessary information.

The development of a marketing strategy means the activity of detailed analytical processing of available information, its rethinking and the development of fundamental marketing objectives for the project. Such important objectives include determining the structure of the project's goals, developing a basic strategy and its individual significant aspects.

It is not entirely traditional to single out the formation of the marketing concept as an independent block. But, in fact, it is present in both theory and practice of project marketing. The marketing concept can be defined either as a strategic aspect of a practical set of marketing activities or as an operational aspect of the marketing strategy. In any case, the marketing concept is a tactical cut of the entire marketing activity, which defines medium-term, important (but not universally important for the entire project, unlike the strategy) directions, targets, and selected methods of implementing measures. Formation of the marketing concept.

The concept of marketing as its tactical component leads to the operational component - practical marketing tools, which are presented in the form of a programme of specific measures to implement the previously formulated project marketing strategy and tactics.

The marketing budget is a mandatory component of the project. In general, it is a plan of cash receipts and payments related to the implementation of the marketing programme.

The final stage is the direct implementation of all marketing activities, both those previously planned and those caused by deviations.

Marketing research

The structure of marketing research can be divided into 3 main blocks, which, in turn, also consist of specific activities:

" Research organization:

– defining the objectives, scope and programme of marketing research;

– determination of methods and means of marketing research;

– collection and initial evaluation of information;

" External analysis:

– analysis of the target market structure;

– analysis of market capacity;

– analysis of sales channels;

– analysis of competition;

– macroeconomic analysis;

– analysis of the socio-economic environment;

"Internal analysis:

– analysis of project participants and their resources;

– analysis of available technologies;

– analysis of project products.

The methodology of organizing and conducting marketing research is described in detail in the specialized literature, so below is only a general description of research and several examples of effective methods.

The organization of research is a crucial stage (block) in terms of optimizing costs and improving the reliability of estimates. There are 3 fundamental requirements for market research that are extremely important for project management. First, the system of interaction between the project and the market must be "transparent" to management; second, existing market constraints and problems must be formulated; and third, the field of potentially possible project options must be identified.

The range and depth of market research is determined by the complexity or novelty of the problems facing the project, as well as the importance of the latter for the project.

Determining the appropriate methods and tools for conducting marketing research should be consistent with the goals and limitations set.

A rather important point in conducting research is the assessment of the necessary and sufficient amount of information. Since the collection of information and the information itself are expensive in today's economy, the collection process requires adequate management.

The content of the analysis described above is the most typical for project management. However, in some cases, the latter have significant specifics that require changes in the content and methods of analysis. The composition of external and internal analyses should be adjusted in each specific project, but the basic set usually remains unchanged.

The external analysis can be described as follows.

Market structure analysis is usually the identification and quantification of different market segments. In this regard, there are many models of market segment analysis, which are a combination of different criteria (or directions) for segmenting (structuring) the market.

Such criteria may include consumer segmentation:

– from the benefits derived from the use of the goods;

– by way of life;

– gender;

– geographical;

– by consumer situations;

– taking into account the rules (strategies) for choosing goods;

– by brand loyalty;

– by price sensitivity;

– using classifiers of national economy sectors (usually used for corporate clients);

– by the method of purchase.

Market capacity analysis is aimed at determining the goods actually sold in a given market segment(s), as well as forecasting potential sales. When analysing market capacity, it is very important to identify and take into account seasonal or other fluctuations in sales.

Below is an example of formulas for determining the demand for a project's products.

Formula for estimating demand for a particular product:

$$c = \sum_{i=1}^{m} n_i \cdot a_i \left(\frac{1}{b}\right) \cdot p,$$

where C is the demand for a given product;

n_i – number of potential consumers in each consumer group;

a_i is a coefficient that takes into account the income of each consumer group and the share of this income that can be used to purchase the product,

b – average product life,

p is the possibility of purchasing (desire to purchase) the product in question.

The value of the probability is determined by the functional purpose of the product and its attractiveness to each age and/or social group, and even the order of satisfaction of this need. With equal probability of purchasing or not purchasing a product, $p = 0.5$.

The so-called chain relationship method can be used to estimate demand. It can be used for both capital goods and consumer goods.

For example, a company that manufactures CNC machines is planning to expand its production. It needs to find out whether the market capacity will be sufficient to recoup the costs of expanding production.

Calculation formula:

$$E = N \cdot P \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4,$$

where E is the demand for CNC (computer numerical control) machines;

N – the number of enterprises consuming the product in question;

P – average profit per enterprise;

K_1 is the average share of profit spent by enterprises on technical re-equipment and reconstruction of their production;

K_2 is the share of expenditures on machinery and equipment in the share of profit, determined by the coefficient K3;

K_3 is the share of expenditures on metalworking equipment in the amount of expenditures determined by the coefficient K2;

K_4 – the projected share of expenses for CNC machines in the total expenses, determined by the coefficient K3.

Market structure analysis and market capacity analysis are very closely related and should be carried out jointly.

Distribution channel analysis is aimed at assessing existing and/or designing optimal chains that link a project with the end users of its products.

Traditionally, 3 types of sales are studied:

– sales through wholesalers;

– sales through retailers;

– sales directly to consumers (direct sales).

When analysing competition, attention is paid to competition both between producers and between products.

There are usually 5 factors that require detailed analysis:

– current competitors;

– the likelihood of new competitors;

– probability of emergence of substitute goods;

– the ability of the consumer to make deals;

– the ability of the supplier to make deals.

Macroeconomic analysis is aimed at identifying existing trends in the global and national economies in the sectors and aspects of interest.

The purpose of the socio-economic environment analysis is to identify social and socio-economic aspects relevant to the preparation and evaluation of the project strategy and marketing concept. These aspects may reflect the society and its culture, social and economic policies in the regions, as well as existing rules, traditions and customs.

As part of the internal analysis, the first step is to analyse the project participants and their resources, where information about the potential strengths and weaknesses of the project is collected and processed.

One of the most important success factors in today's economy is advanced technology. The analysis of available technologies is aimed at assessing the technology market, selecting technological series, determining the requirements for the use of technology (capital investment, level of knowledge and skills, management system, etc.).

The analysis of project products involves comparing the projected products with existing and/or "ideal" products, i.e. those presented by buyers. Analytical positioning tools are used for this purpose. These tools, as well as the results of product analysis, are used for target positioning. These tools include:

– building profiles;

– positioning based on brand similarity;
– multidimensional positioning (including dynamic);
– hierarchical cluster analysis;
– cluster positioning (including multidimensional);
– positioning in relation to "ideal" goods;
– positioning with the use of conjoint analysis;
– positioning in relation to market segments;
– positioning based on useful properties.

The results of marketing research are needed, first of all, to develop a marketing strategy for the project.

Formation of the project marketing concept

The marketing concept is a tactical cut of all marketing activities, which defines medium-term, important (but, unlike the strategy, not universally important for the entire project) directions, targets, and selected methods of implementing the previously defined strategy.

Product and project positioning begins with the definition of the product-market-technology complexes, based on the recognition of the fact of multidimensionality and heterogeneity of the economic space in which the project is implemented. The dimensions of "product", "market" and "technology" are basic and inherent in any economic space, which is structured in its own way in each dimension, but at the same time, there are dependencies (not mathematical or even statistical - rather, logical, based on the existing structure of the economy) between these dimensions. The product-market-technology complexes determine which products will be sold in which markets and with the help of which technologies they will be produced and promoted. A project may have several product-market-technology complexes.

The target positions of the project products are determined with the help of the positioning tools already discussed, which are used in the analysis of the project products. However, if these tools were used to determine the "as is" state, here the target product positions are determined, i.e. the "as should be" state.

One of the important elements of the project concept is the product life cycle model.

Different marketing activities are carried out in different phases of the life cycle, and marketing tactics also change significantly depending on the life of the product.

The product development stage is preparatory, but it is the stage where the main decisions on the product and marketing of the project are made, which determine further development. There are two main components at this stage:

– marketing research;

– selection and preparation of the target audience.

The market entry stage (or introduction stage) is characterised by slow sales growth. When entering the market with a product in this phase of the life cycle, you can vary the price, distribution system, sales promotion costs, and product quality. There are 4 variants of marketing decisions in phase 1:

– intensive marketing;

– selective penetration;

– wide penetration;

– passive marketing.

If the product is at the stage of maturity, the following marketing decisions can be made:

– sales expansion;

– market modification;

– modification of the product;

– modification of the marketing concept.

For most products, the time finally comes for a noticeable decline in sales - the decline stage begins.

Depending on the specific conditions, project managers can choose 3 options:

– reduce the volume of production and the number of outlets where the product was sold,

– "revive" the product by modifying it, changing the packaging, organising new forms of sales, etc,

– to stop production and organise a quick sale at low prices (to avoid overloading the distribution network).

Competitive tactics are formed on the basis of decisions on the product life cycle. The development of competitive tactics is also based on the analysis of competition, the target positions of the project and its products, and the chosen basic strategy. The tactics include the basic principles of relations with competitors and measures to neutralise the negative and use the positive aspects of competition.

The development of the marketing focus areas is aimed at developing aggregated measures in important areas of practical marketing:

– product;

– price;

– sales;

– promotion.

They represent a single system, usually called the mnemonic formula "4P" (from the initial letter of 4 English words that denote the above important areas of practical marketing: product, price, place, promotion). The enlarged activities identified at this stage are subject to more detailed elaboration to form the project marketing programme.

Project marketing programme

The project marketing programme is a set of practical, short-term measures to implement the previously formulated project marketing strategy and tactics (concept). The programme is directly based on the marketing concept.

The main areas of practical marketing have been covered in great detail in the modern literature, so we will focus only on certain concepts of a large and complex set of knowledge and practical marketing skills and start with product management.

The breadth of the product set is the variety of products (product line) of the project. At the same time, the products do not necessarily have to be perceived as technologically related product lines (ranges). When choosing the width of the project's product mix, certain principles should be followed:

– the wider the product range, the more flexible and sustainable the project;

– the wider the product mix, the more capital investment is required for the project.

The depth of the product set is the number of modifications of one type of product, i.e. the number of product models that can be produced on the basis of one technological (product) line. In this case, the differences between these models may be insignificant in terms of technology, but through the implementation of product promotion measures, they can be perceived as very significant. General principles regarding the depth of the product range:

– the deeper the product set, the easier it is to implement a strategy of concentrating efforts on a market niche;

– the deeper the product set, the potentially longer the project life cycle.

A necessary (but not always sufficient) requirement for successful project implementation is the quality of the project's products.

Equally important are measures aimed not so much at the product itself, but at the target audience and the creation of stereotypes of perception of this product. Such measures include defining requirements for design and packaging, related services (such as delivery, installation), and maintenance.

A modern successful product is a simple material object designed to be used for certain purposes, but only to a limited extent. In fact, a modern commodity is a complex set of socio-economic relations in which a material object is not always central. Commodities include a very wide range of different relations, ranging from narrowly economic ones, such as price, to aspects of social psychology and psychoanalysis. For a project to be successful, the most important aspects of these socio-economic relationships must be identified and measures to successfully establish and maintain them must be carefully considered. This is the focus of the practical marketing programme.

Price management broadly includes price formation and the development of a system of discounts and payment terms, but is preceded by measures of a general economic nature:

- formulation of pricing objectives;
- correction of demand;
- cost estimation;
- analysis of competitors' prices and products;
- Selection of the pricing method;

Determining the final price and the range of its possible change.

Before entering the market, it is necessary to adjust the project goal for a particular product. This task has already been determined during the market analysis and preparation of the marketing concept. During the course of the project implementation, changes may have occurred in the market, which should be taken into account to clarify the project goal.

There are various options for this:

- Prices are based on sales criteria, i.e. the project aims to achieve high sales or increase its sales share compared to competitors. For these purposes, the so-called penetration price is often used, i.e. a reduced price designed to capture the mass market for goods or services;

- Prices based on maximising current profits. There may be a situation when a project seeks to make a quick initial profit because it lacks funds or is uncertain about the future. In this case, demand and costs should be assessed for different price levels and the price that will maximise current profits should be chosen;

- Prices are based on gaining leadership in terms of product quality. A project may aim to ensure that its product is of the highest quality available on the market. This requires setting a high price because it is necessary to cover the costs of achieving high quality;

- Survival-based pricing becomes the main focus for a project when there are too many competitors in the market or when customer needs change dramatically. Survival becomes more important than profit. To ensure that production capacities are utilised, hoping to increase sales, the project is forced to set low prices. As long as the reduced prices cover costs, the project can continue to operate for some time.

Now, based on the preliminary estimate of demand obtained during the market research, it is necessary to adjust the amount of demand at different prices (by conducting surveys, trial sales in a particular region or store, etc.).

For most goods, demand and price are inversely related, i.e. the higher the price, the lower the demand. However, with prestigious goods, it is sometimes the case that a certain price increase is interpreted by the buyer as an increase in consumer value, which results in an increase in demand.

When determining the relationship between price and demand, it should be remembered that other factors besides price may affect the amount of demand (e.g., intensified advertising, etc.).

It is also necessary to investigate the price elasticity of demand; i.e. how sensitive demand is to price changes. Demand will be less elastic in such circumstances:

– there is a shortage of goods on the market;

– price increases are hardly noticeable to consumers;

– buyers are slow to change their consumption habits and are not in a hurry to look for cheaper goods;

– buyers believe that the price increase is due to improved quality of the goods, higher inflation, etc.

If it turns out that the demand is elastic, it is advisable to raise the issue of price reduction. A reduced price will increase the total amount of revenue.

The maximum price that can be charged for a product is determined by demand, and the minimum price is determined by costs. The price to be set by the manufacturer should fully cover all costs of production and circulation of the product, including the profit for the efforts and risk involved.

Next, it is advisable to repeat the research on prices and competitors' products conducted in the course of market research, as changes may have occurred in the market since then.

Having determined the relationship between demand and price, the estimated amount of costs and the prices of competitors, you can set the price of your product. The following considerations should guide you in setting the price. The minimum possible price, as noted above, is determined by the costs of production and circulation, while the maximum price is determined by the presence of certain unique advantages of the product. The prices of competing products provide an average level that should be followed in pricing.

Once the pricing policy is implemented, it should be constantly adjusted to reflect changes in costs, competition and demand.

The third basic area of the marketing programme is promotion management.

Promotion is any form of messaging used by project management to inform, persuade, or remind people about products, services, ideas, and community activities.

A project may communicate the necessary messages through brand names, packaging, shop displays, personal (personal) sales, industry trade shows, lotteries, mass media, etc.

Consumers should be informed about new products and their characteristics before they have formed an attitude towards them.

In the case of well-known products, the main thing in promotion is persuasion, namely, it is necessary to turn knowledge about the product into a favourable attitude towards it.

For products that are firmly established in the market, the emphasis should be on strengthening existing consumer attitudes.

Promotional efforts should be directed to consumers, shareholders, consumer associations, government, channel members, their employees, and the general public.

Information should be exchanged with each of these groups, and in different ways, as they have different objectives, knowledge and needs. Within these groups, opinion makers should be identified and contacted.

The promotion programme can highlight individual products or services. Depending on the circumstances, it is also possible to create a general image of the enterprise participating in the project (e.g., as an innovator in the industry, etc.), its position on an issue (e.g., publicising the funding of a free canteen for the poor), and efforts to impact society (e.g., indicating the number of new jobs associated with the investment project).

Project management may use 1 or a combination of the 5 main types of promotion:

– advertising;

– PR (public relations), or publicity;

– personal selling;

– sales promotion;

– brand management.

Advertising is a system of activities paid for by a particular customer, aimed at communicating specially selected and processed information about a product, service or project to the consumer. Advertising targets large audiences. Without it, personal selling will be significantly hindered and will require more time and money.

PR activities, or propaganda - a system of public relations, press, various institutions and organizations (including elected ones) and formation of a positive attitude of potential consumers to a certain product or project with their help. This form of promotion is closely related to advertising practice, but, unlike advertising, is conducted mainly on a non-commercial basis. Propaganda provides reliable information to a wide audience, but its content and timing cannot always be controlled by project management. It stimulates demand for a product or service by placing commercially important news items in the media or by generating favourable publicity on radio, television or stage that is not paid for by a particular sponsor.

A favourable public perception should be based on the idea that the project is primarily in the public interest and not for profit. This concept should be communicated to the public (not in such a blatant way, of course) through the press and television, through a series of events, the main ones being press conferences, non-commercial articles, TV films, TV reports, public and charitable activities, various anniversary events, annual business reports, visits to the investment project site, and familiarisation with the construction of the facility.

These ways of communicating information emphasise the focus of the project, showing its role in, for example, environmental protection, creating new jobs in the local area, etc.

Personal (personal) selling is a form of promoting products and services, including their demonstration and oral presentation by a sales agent (salesman) in personal contact with one or more potential customers. Without personal selling, the initial interest generated by the advertisement will be lost.

Unlike advertising and opinion moulding, this method requires personal contact with consumers. The goals of this form of promotion are similar - to inform, persuade, and/or remind.

Emphasis on personal selling must be made in many cases. Customers making large-scale purchases require special attention. Specially manufactured, expensive, complex products or services require detailed consumer information, demonstrations, repeat visits to potential buyers. Additional services such as gift wrapping, delivery, and installation may be required during the sale. If advertising provides insufficient information, issues may only be resolved through personal selling. This method may be necessary for the market to recognise new products.

Sales promotion is a marketing activity other than that which encourages consumers to make purchases and enhances the effectiveness of the sales network. This form leads to a short-term increase in sales and complements the types of promotion already described.

It includes exhibitions, demonstrations, prizes, competitions, distribution of samples, discounts, targeted window dressing, etc.

There are limitations to sales promotion. If the project management continuously promotes sales, its (sales) image may deteriorate. Consumers will see, for example, discounts as a symptom of deteriorating product quality and believe that the project management cannot sell it without it, etc.

Brand management is a series of activities to renew the positive perception of a range of products in order to create an exceptional customer relationship with them. Trade mark management (or brand management) is successfully used mainly in the production and sale of consumer goods.

Sales management, i.e. the development of the sales system, the choice of the scheme through which the products will be sold and its main characteristics (density of the sales network, time indicators of the realisation of transactions, trade stocks and transport) are carried out on the basis of the following approaches:

– intuitive - the project management chooses the way of product realisation on the basis of intuition and available experience;

– trial and error method - the project enters the market independently, without using the services of intermediaries. The optimum variant is chosen on the basis of accumulated experience and using new opportunities opened in the process of work;

– marketing analysis - a large-scale study of the market capacity is carried out after its preliminary segmentation. Information is collected on the advantages and disadvantages of all links of a particular sales system.

TOPIC 4 GENERAL ORGANIZATIONAL PREPARATION FOR THE PROJECT

Questions for theoretical preparation

4.1 General organizational preparation for the project.

4.2 Tenders.

4.3 Contractor agreement.

4.1 General organizational preparation for the project

General organizational preparation is carried out by the customer. The timing of their implementation is not regulated by standards. For complex facilities, the content of the measures and the timing of their implementation are determined by the decision-making bodies that make the decision on construction.

Participants in the investment process distribute responsibilities for general construction preparation among themselves when drafting protocols of intent and construction contracts, taking into account the specifics of the facility being created, the conditions of its construction, the scope of work covered by the contract, the composition of the contract participants and other conditions.

General organizational preparation is carried out in the following stages:

1. Pre-contractual work in cases of direct negotiations and when tenders are announced.

Direct negotiations are held between the parties in the following cases:

– on the basis of long-term and trusting relations between the client and the general contractor;

– in the case of long-term phased development of investments by the general contractor in a given building;

– in case of necessary clarifications of the scope, composition of works and price during the contract execution;

– when carrying out repair works, restoration of other similar works, if they are carried out in small volumes;

– in case of unsuccessful previous tenders;

– especially urgent work;

– impossibility of holding tenders based on the specifics of the general contractor's monopoly position.

Participants in direct negotiations who have agreed to enter into a contract execute pre-contractual agreements in the form of a protocol of intent, by which they assume mutual obligations. The protocol of intent is a binding legal document for the parties to execute, and if one of the parties refuses to enter into a contract, the latter shall compensate the weight of the costs incurred voluntarily or by arbitration.

Tenders (competitions) are held at the stages of design, supply or procurement of construction of facilities, etc. They are conducted by customers with the establishment of tender committees. Based on the customer's requirements and data, bidders prepare a set of documents that provide for proposals and conditions on which they agree to fulfil the order.

2. Contracts for the construction of facilities under the project are concluded after direct negotiations and execution of a protocol of intent by the participants, as well as after receiving an order as a result of the tender.

Prior to the conclusion of contracts, the customer and the contractor carry out preparatory work in terms of preparing contract documents and special conditions for the execution of the contract. Personal responsibility for the timing and preparation of contract documents, including the transfer of the site for the construction of the facility, technical documentation, equipment, work schedules, material and technical resources, comprehensive equipment adjustment, etc. is established.

3. Contracts with subcontractors shall be concluded on the basis of distribution of total volumes by type of work among contractors depending on the specifics of work performed by the subcontractor and its specialisation. Such specialised works, which determine the subcontractor's work profile, include

– general construction works;

– construction of complex foundations, including pile foundations;

– installation of frames of complex buildings and structures;

– plumbing and ventilation works;

– electrical installation works;

– installation of technological equipment;

– finishing works;

– specialised works on installation of lifts, control and alarm systems, fire alarms, fuses;

– specialised works on external communications, structures, etc.

Preparation for the conclusion of contracts with subcontractors and their procedure is similar to the conclusion and procedure between the client and the contractor.

4. Searching for suppliers of materials, structures, equipment, entering into contracts with them, and organising deliveries to the construction site.

The logistical support for the construction of a facility is one of the most complex and crucial stages in the project implementation and involves the selection of appropriate suppliers based on an assessment of their capabilities. These capabilities include:

– management, technical and production capabilities;

– availability of direct long-term relationships;

– financial position;

– product quality (sample evaluation, test results, etc.)

– documented feedback from other customers (consumers), etc.

Taking into account these requirements, a list of potential suppliers is drawn up with whom a contract for the supply of equipment and material resources may be concluded. The list is prepared for each procurement method, approved by the customer and may be a potential list for bidding. Particular attention should be paid to transport costs when selecting a supplier.

After the supplier is selected, certain preparatory work is carried out before the supply contract is concluded, which includes the following:

– requisitions for the supply of material resources are prepared and sent to suppliers;

– after receiving proposals from suppliers and assessing their capabilities, a meeting of the parties is held;

– purchase orders are prepared and delivery issues are resolved with a programme of delivery and transport guarantees;

– quality control and the implementation of the transport programme are agreed upon.

A supply contract is concluded in writing with the resolution of preliminary issues regarding the volume and range of material resources to be supplied, delivery time, price, quality, acceptance, and property liability.

The supply of material resources to the facility under construction is organised by the procurement departments and, for large construction projects, by the technological equipment departments. Annual, quarterly, and monthly planning of material resources for construction is carried out by production departments, and organizational operational control is carried out by dispatch services.

Material procurement should be planned and coordinated with work schedules, taking into account the change order.

5. Providing construction with design and estimate documentation is the responsibility of the customer and is developed by design organizations or by the customer himself.

In the event that the technical documentation is developed by the contractor (design and construction organization), the development of design and estimate documentation is the responsibility of the contractor. At the same time, the development of design documentation should be ahead of the construction and installation works (CIW). It has been established in practice that the start of construction and installation works can be performed when the design work is 25-30% complete, and when 25-35% of the design work is completed, the readiness of the design work should be 50%. 50% of the construction work performed coincides with the period when the project is 65-75% complete. The point of 85% completion of design and construction works determines the start of equipment installation.

This method of combining design and construction is widely used in construction and allows reduce the duration of investment by 30-40%, construction by 20-30% and reduce project implementation costs by 10-12%.

6. The site (route) for construction shall be allocated in kind, taking into account the requirements of the interested local self-government bodies (organizations) and state supervisory authorities. The following issues are considered when selecting a site:

– location and size of the construction site;

– possibilities of using local material resources;

–technical conditions for connecting the projected facility to existing engineering networks and communications;

– laying new routes for external networks and communications;

– measures to protect the environment, preserve architectural, cultural, historical, fire and labour safety monuments;

– measures related to flooding of the site, as well as other requirements.

The responsibility and coordination of these requirements lies with the customer.

Upon acceptance of the site (route) by the general contractor from the customer, the customer shall provide a geodetic base with a breakdown of axes and routes with their fixation in kind.

7. Resolving the issues of financing the construction of the facility and financial guarantees determine the life of the project in its management. It must be confirmed by the financing banks and is aimed at:

– timely provision of project investments necessary for its smooth implementation. Timely financing of the facility under construction allows for the acquisition of material and technical resources, payment of wages and ensures the rhythmic operation of project implementation within the established timeframe and according to the schedule;

– reduced capital expenditures and project risk through an optimal investment structure and tax advantages.

A project can be financed by one or more investors. Co-investment has advantages as it creates conditions for obtaining a larger loan, which ensures the required level of investment flow and project financing at lower costs. Tax advantages are achieved by transferring ownership of all or part of the project to investors who currently enjoy tax benefits.

8. Clearing the site for construction, demolition and construction of buildings to replace those being demolished are the responsibility of the customer. These works can be performed by the contractor for a fee under the contract and carried out before the start of construction of the facility.

9. Obtaining various permits and approvals for the performance of works is carried out before the start of works and is the responsibility of the customer and is carried out within the terms specified in the special conditions to the contract.

4.2 TENDERS

Normative literature:

DSTU ISO 20400:2019 Sustainable procurement. Guidelines (ISO 20400:2017, IDT);

LAW OF UKRAINE;

On Amendments to the Law of Ukraine "On Public Procurement" and Some Other Legislative Acts of Ukraine on Improving Public Procurement.

(Bulletin of the Verkhovna Rada (VRU), 2019, No. 45, Art. 289).

During the period of martial law in Ukraine, public procuring entities conduct public procurement under four types of procurement procedures. These conditions are approved by the Resolution of the Cabinet of Ministers of Ukraine No. 1178 of 12.10.2022 "Peculiarities of Public Procurement of Goods, Works and Services for Customers Provided for by the Law of Ukraine "On Public Procurement" for the Period of Legal Regime of Martial Law in Ukraine and within 90 days from the date of its termination or cancellation"

https://prozorro.gov.ua/search/tender

Tender is a competitive form of placing an order for the procurement of goods, services or works in accordance with the conditions specified in the documentation within the agreed timeframe on the principles of generality, fairness and efficiency.

The contract is concluded with the successful tenderer, i.e. the tenderer who submitted the offer that complies with the tender documentation and provides the best terms and conditions.

The tender documentation is essentially a guide for contractors and suppliers to prepare their bids. It specifies the qualification criteria for suppliers, technical, qualitative and quantitative characteristics of the procurement item, attaches a draft contract, indicates the criteria and methodology for evaluating tender proposals, information on language, currency, etc. A detailed list of information to be included in the tender documentation is provided in Article 22 of the Law of Ukraine "On Public Procurement".

https://infobox.prozorro.org/news-mert/nakaz-minekonomrozvitku-680-pro-zatverdzhennya-primirnoji-tendernoji-dokumentaciji

A tender offer is an application of a supplier of services, works or goods to participate in a specific public or commercial procurement or part of it (if the participant applies for one or more lots), prepared and submitted in accordance with the applicable law and the requirements of the tenderer.

What does a tender offer consist of?

The tender proposal shall include the proposed price for the subject of procurement and copies of documents confirming the supplier's compliance with the terms of the electronic tender.

The bid can be divided into two parts:

– an electronic form - it contains the price, delivery terms, payment terms, electronic fields regarding the absence of grounds for disqualification of the supplier, etc;

– scanned copies of documents or electronic documents attached as files in a format acceptable to the procuring entity (PDF, DOC, etc.), which confirm that the supplier and what he offers meets the requirements of the procuring entity and the law.

What documents may be required as part of the tender offer

The contents of the tender offer depend on the procuring entity's requirements, which it specifies in the tender documentation, and may differ from one online tender to another. For example, when procuring goods, a bidder may be required to submit documents relating to:

1) quality of raw materials and products

2) compliance of production and transport equipment with Ukrainian regulations

3) the level of qualification of employees, whether they have health certificates, driving licences, etc;

4) availability of material and technical facilities.

Closed tender

A closed tender is a type of electronic tender that involves only those contractors selected by the procuring entity. Invitations to participate in the tender are sent out directly by the procuring entity, and information about the procurement is not publicised.

Reasons for holding a closed tender

Some public procurements by government agencies are related to security issues or other areas classified as "secret". In this case, the customer holds a closed tender to keep the information secret.

In addition, both public and commercial procurement may be conducted under this form of procedure if only a limited number of potential contractors with the necessary qualifications and experience have the required qualifications.

The choice of a closed procedure is economically and rationally justified, but not mandatory. In some cases, such a tender must be agreed with the regulatory authorities to confirm the need for this particular procedure.

The closed tender procedure consists of seven steps:

1 Sending out invitations to tender to the desired contractors.

2 Contractors request tender documents and clarify the terms and conditions.

3 Preparation and submission of tender proposals.

4 Procedure of opening of tender proposals with the participation of all potential contractors.

5 Qualification of participants.

6 Negotiation and price reduction.

7 Selection of the winner.

Conclusion of the contract between the procuring entity and the contractor.

When working on a closed tender on the SmartTender.biz platform, it is important to keep in mind that the procuring entity is obliged to provide clarifications on the tender documentation upon request, but also has the right to make changes to it at any time.

As part of this procedure, online bidding takes place after the customer evaluates the proposals based on predefined criteria - the most suitable candidates are invited to negotiate, during which all reduce the cost of the proposals. A cooperation agreement is concluded with the successful bidder.

Open tenders

An open tender is a type of online bidding in which any company can participate. This is the main type of procurement procedure that ensures maximum competition and, accordingly, the most cost-effective terms of offers for the customer. https://smarttender.biz

Open tenders are one of the main and most commonly used procurement procedures.

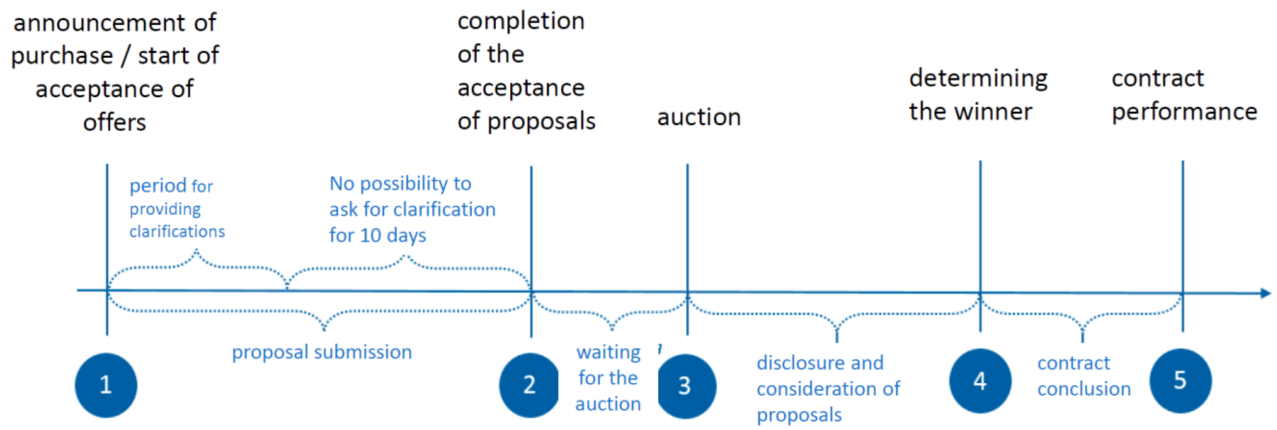
There are two types of open bidding procedures:

- open tenders (so-called "Ukrainian");

- open tenders with publication in English (so-called "European").

Stages of open bidding

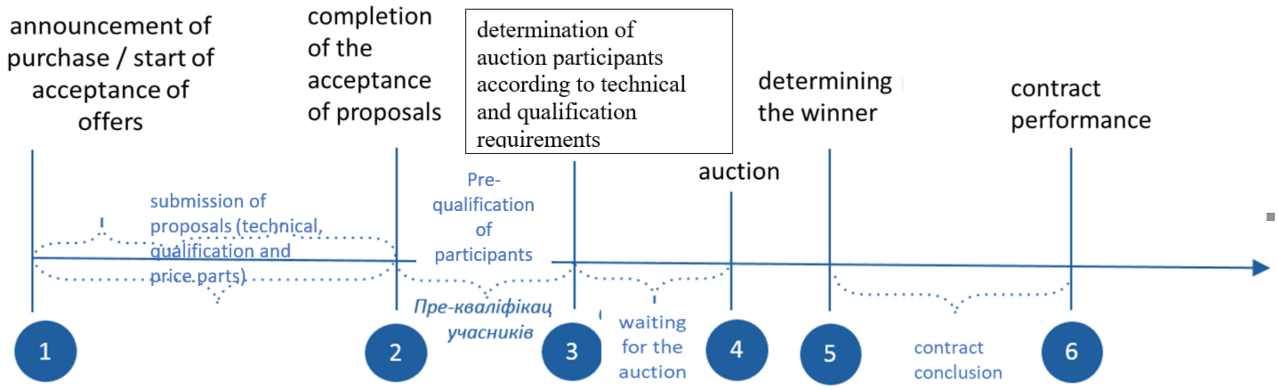
In general, the open bidding procedure ("**Ukrainian**") can be divided into 5 stages, as shown in the diagram below:



Open Bidding with publication in English

The main feature of Open Bidding with English-language publication is an additional period - Pre-qualification. https://infobox.prozorro.org/articles/procedura-vidkriti-torgi

During pre-qualification, all documents of suppliers are opened, except for the price part. The Employer shall review all documents of suppliers opened during the prequalification. The price part of the proposals will be opened after the auction.



4.3 Contractor agreement

A contractor agreement is an agreement between two parties under which one party (the contractor) undertakes to perform certain work at its own risk on behalf of the other party (the customer), and the customer undertakes to accept and pay for the work performed (part one of Article 837 of the Civil Code of Ukraine).

A contractor agreement may be concluded for construction works; manufacturing, processing, and processing of materials and structures; repair works; and other works with the transfer of the results to the customer.

To perform certain types of work established by law, the contractor (subcontractor) must obtain a special permit.

A contractor agreement is deemed to be concluded from the moment the parties reach an agreement on all material terms of the agreement (consensual agreement).

Types of contractor agreements: construction; design and survey work; research and development or development and technological work.

Under a contractor agreement, the contractor undertakes, at the request of the employer, to perform and deliver the completed works (construction object) to the employer at his own risk within the time period specified in the contractor agreement, and the employer undertakes to provide the contractor with a construction site (work site), transfer permits and duly approved design documentation (if this obligation is not fully or partially imposed on the contractor), accept the completed works (construction object) from the contractor and pay for them (part 1 of Article 875 of the Civil Code of Ukraine, paragraph 4 of the Resolution of the Cabinet of Ministers of Ukraine No. 668 dated 01.08.2005).

A construction contract is concluded for new construction, major repairs, reconstruction (technical re-equipment) of enterprises, buildings (including residential buildings), structures, installation, commissioning and other works inextricably linked to the location of the object.

The contractor agreement is concluded in writing; at the request of the parties, the agreement may be notarised.

Subject matter of the contractor agreement

The subject matter of a contractor agreement is work related to the construction of a facility, the obligation to perform which is imposed on the contractor.

The owner of the result of the work performed (the construction object) is the customer, unless otherwise provided by the contract.

In the contractor agreement, the parties are obliged to determine the name of the construction object and its location, the main parameters (capacity, area, volume, etc.), the composition and scope of work provided for in the project documentation and to be performed by the contractor, and other indicators characterising the subject matter of the agreement.

Timeframe for performance of works (construction of the facility)

The terms of performance of works (construction of a facility) are set out in the contractor agreement and are determined by the date of their commencement and completion. An integral part of the contractor agreement is the schedule of works, which sets out the start and end dates of all types (stages, complexes) of works provided for in the contractor agreement.

The parties to a construction contract may set deadlines for the performance of works (construction of a facility) in connection with the performance of certain obligations by the customer (provision of a construction site (work front) to the contractor, transfer of project documentation, opening of financing, payment of an advance, etc.).

The date of completion of the works (construction of the facility) is the date of their acceptance by the customer. The performance of works (construction of the facility) may be completed ahead of schedule only with the consent of the customer.

The terms of performance of works (construction of the facility) may be changed with the introduction of appropriate amendments to the contractor agreement in the event of:

– force majeure circumstances;

– non-fulfilment or improper fulfilment by the customer of its obligations (violation of financing terms, untimely provision of the construction site (work front), project documentation, resources, etc;)

– amendments to the project documentation;

– actions of third parties that make it impossible to perform the work properly, unless such actions are caused by circumstances beyond the contractor's control;

– occurrence of other circumstances that may affect the timeframe for the performance of works (construction of the facility).

The customer may decide to slow down the pace of work (construction of the facility), suspend or accelerate it with appropriate amendments to the contractor agreement.

Estimate

The contract price in a construction contract shall be determined on the basis of an estimate as either approximate or firm. The contract price shall be deemed fixed unless otherwise provided by the contract.

If the contractor agreement is concluded based on the results of a tender, the type of contract price and the requirements for the estimate are determined in the customer's tender documentation. In this case, the contract price shall correspond to the price specified in the tender offer of the contractor who was declared the winner of the tender.

If the contractor agreement is concluded as a result of negotiations between the parties, the decision to apply an approximate or firm contract price, the procedure for approving the estimate and making payments shall be made by agreement of the parties.

If the works (construction of the facility) are financed with public funds, the contract price shall be determined in accordance with the requirements of regulatory documents in the field of pricing in construction.

Approximate contract price

If, at the time of entering into a construction contract, it is impossible to establish the contract price definitively due to uncertainty of costs or other circumstances, the parties to the construction contract shall determine the approximate contract price and the procedure for its adjustment in the course of performance of works (construction of a facility). The approximate contract price may be adjusted as the work is performed, the contractor's expenses are incurred, etc.

If circumstances arise that necessitate a significant increase in the approximate contract price (more than specified in the contract), the contractor shall notify the customer within the time limits established by the contract. If the contractor fails to notify the employer of the need to increase the contract price in accordance with the established procedure, the contractor shall be obliged to perform the work without reimbursement of additional costs.

Firm contract price

The firm contract price may be adjusted only by mutual agreement of the parties. If the contractor increases the firm contract price without being provided for in the contract, all related costs shall be borne by the contractor, unless otherwise provided by law.

The parties to the contractor agreement may stipulate the procedure for adjusting the firm contract price in the event of:

1) occurrence of force majeure circumstances;

2) amendments to the project documentation;

3) the need to eliminate deficiencies in the works arising from non-compliance with the established requirements of the project documentation, which is the responsibility of the client;

4) slowdown or suspension of works by the client's decision or through his fault, if this caused additional costs to the contractor;

5) changes in taxation legislation, if this affects the cost of the works;

6) a significant increase (in the amount determined by the parties) after the conclusion of the contractor agreement in the prices of resources provided by the contractor, as well as services provided by third parties;

7) in other cases stipulated by the contractor agreement.

The contractor may not demand clarification of the approximate or firm contract price due to an increase in prices for resources used to perform the work, if the deadlines for performing the work are violated through the fault of the contractor. In such cases, unless otherwise provided for in the contract, prices for resources are determined in accordance with the prices in force on the date of completion specified in the contract. The contractor shall be compensated for additional costs associated with the increase in resource prices after the specified date.

Performing additional works not included in the project documentation

If during the construction there is a need to perform additional works not provided for in the project documentation, the provision of which is the responsibility of the employer, and in this regard the firm contract price increases accordingly, the contractor shall, within the period specified in the contract, notify the employer of the circumstances that led to the performance of such works and submit proposals to the employer with the relevant calculations. Within the period specified in the contract, the client shall consider the proposals, make a substantive decision and notify the contractor thereof.

The contractor shall be obliged to suspend the performance of additional works if he does not receive a response to his notice within the time limit specified in the contract. The contractor shall be compensated by the client for the losses incurred by the contractor in connection with the suspension of the additional work. The employer shall be released from compensation for such losses if it proves that there was no need for the additional work.

If the contractor has not notified the employer in the prescribed manner of the need to perform additional works and the corresponding increase in the fixed contract price, he may not demand payment for the additional works performed and compensation for damages incurred, unless he proves that such works were necessary in the interests of the employer, in particular, due to the fact that the suspension of works threatened to destroy or damage the construction object.

Transfer and acceptance of works

The employer who has received the contractor's notification of readiness to hand over the works performed under the construction contract, or, if provided for by the contract, a stage of works, shall immediately begin acceptance of the works.

The client shall organise and carry out acceptance of works at his own expense, unless otherwise provided by the contract. Representatives of state authorities and local self-government bodies shall take part in the acceptance of works in cases established by law or other regulatory legal acts.

The customer who has previously accepted certain stages of the works shall bear the risk of their destruction or damage through no fault of the contractor, including in cases where the construction contract provides for the performance of works at the contractor's risk.

The handover of works by the contractor and their acceptance by the client shall be documented by an act signed by both parties. If one of the parties refuses to sign the act, this shall be stated in the act and signed by the other party.

An act signed by one party may be declared invalid by a court only if the reasons for the other party's refusal to sign the act are found by the court to be justified.

Acceptance of works may be carried out after a preliminary test if it is provided for in the construction contract or follows from the nature of the works. In this case, acceptance of the works may only be carried out if the preliminary test is positive.

The client has the right to refuse acceptance of the works if defects are found that preclude the use of the object for the purpose specified in the contract and cannot be eliminated by the contractor, client or third party.

Quality guarantees in a construction contract

The contractor guarantees that the construction object will achieve the performance indicators specified in the design and estimate documentation and that the object will be able to be operated in accordance with the contract during the warranty period, unless otherwise provided for in the construction contract. The warranty period is ten years from the date of acceptance of the facility by the customer, unless a longer warranty period is established by the contract or law.

The contractor shall be liable for defects detected within the warranty period unless he proves that they occurred as a result of:

1) the defects were known or could have been known to the client at the time of acceptance, but were not specified in the act;

2) the defects arose as a result of:

3) inadequate preparation of project documentation, if, in accordance with the contractor agreement, the obligation to provide the works (construction of the facility) with project documentation was imposed on the customer;

4) natural wear and tear of the result of completed works (construction object), assembled structures;

5) improper operation or incorrect operation instructions for the assembled structures and/or construction object developed by the customer or third parties engaged by the customer;

6) improper repair of the assembled structures, construction object, carried out by the customer or third parties engaged by him;

7) other circumstances beyond the contractor's control.

The warranty period is extended for the period during which the facility could not be operated as a result of defects for which the contractor is responsible.

If defects are detected during the warranty period, the customer must notify the contractor within a reasonable time after their discovery.

A construction contract may provide for the right of the customer to pay the contractual part of the price of the works specified in the estimate after the expiry of the warranty period.

Amendments to the construction contract and its termination

Amendments to or termination of the contractor agreement are permitted only by agreement of the parties, unless otherwise provided by the contractor agreement or law. In the absence of such agreement, the interested party has the right to apply to court.

Amendments to the contractor agreement shall be executed by an additional agreement, which shall be specified in the contractor agreement.

A party to the contractor agreement that considers it necessary to amend or terminate the contractor agreement must send a proposal to the other party.

The party to the contract that has received the proposal to amend or terminate the contract shall notify the other party of its decision within twenty days.

If the parties fail to reach an agreement on amending or terminating the contractor agreement or if they do not receive a response within the prescribed period, taking into account the time of postal circulation, the interested party may apply to the court.

If a court decision amends or terminates a contractor agreement, it shall be deemed amended or terminated from the date the relevant decision comes into force, unless otherwise provided by the court decision.

Liability of the parties for breach of obligations under the contractor agreement and dispute resolution procedure.

In case of breach of obligations under the contractor agreement, the following legal consequences may arise: termination of obligations under the contractor agreement as a result of unilateral withdrawal from the contractor agreement, if provided for by the contractor agreement or law, or termination of the contractor agreement; change of the terms of the contractor agreement; payment of a penalty; compensation for losses and non-pecuniary damage.

If a contractor agreement sets out the amount of a penalty for default, it shall be recoverable in full regardless of any compensation for damages.

The parties are obliged to make efforts to resolve conflicts through negotiations and find mutually acceptable solutions.

The parties may engage professional experts to resolve disagreements where no agreement has been reached. The party that has violated the property rights or legitimate interests of the other party is obliged to restore them without waiting for a claim to be filed or going to court.

Claims procedure

If it is necessary to compensate for damages or impose other sanctions, the party whose rights or legitimate interests have been violated may file a written claim with the violator to resolve the dispute, unless otherwise provided by law.

The claim shall be reviewed within one month from the date of its receipt, unless a different period is established by law. The infringer is obliged to satisfy the claimant's reasonable claims.

Court proceedings

If the party that has violated the property rights or legal interests of the other party fails to respond to the claim within one month or refuses to fully or partially satisfy it, the party whose rights or legal interests have been violated may file a claim with the court.

TOPIC 5 ORGANIZATION OF THE FLOW METHOD OF CONSTRUCTION PRODUCTION

Questions for theoretical preparation

5.1 The essence of the flow organization of construction production.

5.2 Basic principles of flow design.

5.3 Classification of construction flows.

5.4 Parameters of construction flows.

5.5 Basic laws, technological linkage and calculation of construction flow parameters.

5.1 The essence of the flow organization of construction production

The rhythmicity of construction, the use of flow methods is one of the most important areas of construction industrialisation. Documents for organising the flow construction of complexes and individual buildings and structures are developed as part of the PBS and PDS.

The flow method originally appeared in the factory industry. Its emergence was associated with the development of technology and the transition of the industry to mechanised production with division of labour and its co-operation.

The flow method in industry divides the process of processing a part or manufacturing a product into a number of simpler sequential processes. Machines are installed in the order of processing a part or assembling a product, forming a production line. Each machine is a workstation. The product, being processed sequentially, moves from one workstation to another. Because all machines operate simultaneously, several products are processed on the production line at the same time, according to the number of stations; the products on the production line are in different degrees of readiness. The entire group of processed products moves evenly along the production line, and uniformity of movement is one of the main features of the flow method. The conveyor method is a special case of the flow method.

To ensure uniformity of movement, the processing time of the product on each machine must be the same, because otherwise they will accumulate unprocessed products on machines with lower productivity.

The application of the flow method in industry quickly demonstrated its advantages. The flow method significantly increases labour productivity and machine utilisation, accelerates the rate of output of finished products, and reduces the production cycle of product processing.

Modern industrial production is developing on the principles of flow, i.e. continuity and uniformity. Deviations from these principles invariably lead to a decline in technical and economic performance.

The role of flow is also important in modern construction production.

The flow method in construction is fundamentally no different from the flow method in industry, but the specifics of construction production leave their mark on the organization of work in a continuous flow. The difference between the flow in construction is that in industry, workstations are stationary and the product being processed moves from one workstation to another, while construction products cannot move, so teams or units of workers move along the front of the work. The flow in construction production is much more rhythmic than in industry: while in industry the flow step is usually measured in minutes or seconds, in construction it is usually one or more shifts. The organization of flow in construction production is more complex than in industry because the conditions on the construction site change frequently (weather and climate conditions, different stages of work).

The large number, diversity and time-varying composition of workers and construction machines involved in the flow make the flow organization in construction much more complex. In addition, the products of an industrial enterprise remain constant for a long time, and the flow organization remains unchanged throughout this time. In the case of a building constructed using the flow method, however, planning decisions and designs can vary considerably, requiring constant reorganization of the flow.

A flow method is a method of construction organization that ensures a systematic and rhythmic output of finished construction products based on the continuous and uniform work of teams (units) of the same composition, provided with timely and complete supply of all necessary material and technical resources.

Non-flow methods are used in the case of non-rhythmic production of construction products, which is characterised by the production of products at uncertain or different periods of time and in different quantities.

It is no coincidence that flow methods of construction are most widely used at house-building plants (HBPs), where the products are the most homogeneous.

The main principle of the flow method in construction is the full utilisation of the production capacity of the construction organization with uniform and continuous workload of the lower construction units (construction sites, teams, units and individual workers).

When organising a construction flow, a complex construction process is divided into simpler processes or operations. For example, the process of constructing a monolithic reinforced concrete structure is divided into the following simple processes: formwork installation, reinforcement installation, concrete mix placement and compaction, concrete maintenance, and formwork.

Each simple process is assigned to a separate specialised team or unit. The entire work site is divided into several sections (sections). The teams (or units), while maintaining their unchanged composition, move evenly along the general work front, moving from one section to another.

The first team (or link) always performs the first process in the technological order, and the last team leaves the area after its work. Thus, work is carried out simultaneously on several grippers, with each gripper at a different stage of readiness.

The advantages of the flow method were so obvious that it has spread to many construction sites in our country.

The scope of the flow method is very wide: this method can be used to perform individual construction processes (the so-called "flow-split" method), to erect individual buildings (streaming at individual sites) and, finally, to build a whole complex of facilities (flow at the construction of residential areas or industrial enterprises).

The flow construction method has been successfully used in the construction of residential buildings in Ukraine and in Russia, the Baltic States, and on many large-scale construction projects.

The flow method can be used to construct a number of similar complexes located at a considerable distance from each other, such as the construction of a thermal power plant, ore processing plants, etc.

Let us consider the essence and advantages of the flow organization of construction production over other methods using a conditional example of three methods of organising of works.

Let's assume that m identical houses are to be built, with T_c is the duration of construction of one house (the duration of the production cycle).

Let's conditionally divide the process of building each house into three types of work that have the same duration, equal to T_c /3:

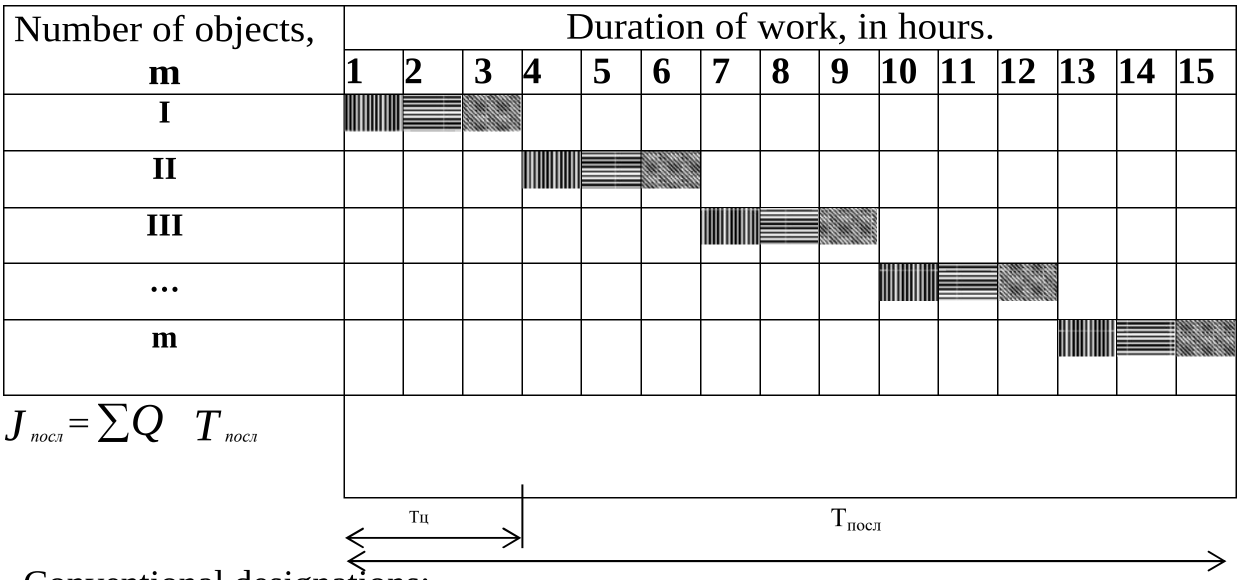
– construction of the underground part of the house;

– installation of the above-ground part;

– finishing works and landscaping.

The number of workers in the teams involved in the work is taken to be r. We consider each individual building to be a unit. Hereafter, for convenience, we denote the units by Roman numerals and the construction works by Arabic numerals.

The construction of these buildings can be organised by the sequential, parallel or flow method: sequential means the sequential construction of all buildings one after the other (Fig. 5.1), parallel means the simultaneous construction of all buildings (Fig. 5.2), and flow is a combination of the first two methods, which eliminates their disadvantages and preserves their advantages (Fig. 5.3).



Conventional designations:

- *construction of the underground part of the house*

installation of the above-ground part of the house

- *finishing works*

Figure 5.1 – Sequential method of building houses

Duration of construction of m houses in the sequential method:

$$T_{seq} = m * T_{ц} . \quad (5.1)$$

The intensity of resource consumption per unit of time:

$$J_{seq} = \sum Q, \quad (5.2)$$

where: $\sum Q$ - total resource consumption for the construction of ***m*** houses.

The sequential construction method has the following advantages:

– the total number of workers employed in the construction of buildings R_{seq} is constant and has the lowest possible value (R_{seq} = r);

– the level of resource consumption is also minimal.

Despite these advantages, this method is not without its drawbacks. The main ones are:

– long overall construction time;

– inevitable downtime of machines and crews, certain difficulties for manufacturing plants, transport and supply organizations due to frequent changes in the types of materials and structures.

The parallel method (Fig. 5.2) significantly speeds up production.

With this method, the same type of work is carried out simultaneously at different sites, and the construction duration is equal to the construction time of one site ($\boldsymbol{T_{par} = T_s}$); intensity of consumption of material and technical resources biggest ($\boldsymbol{J_{par} = \sum Q\ T}_{\text{par}}$). With the parallel method, the construction of all the buildings starts and completes the construction of all buildings at the same time.

Number of objects, m	Duration of work, in hours.		
	1	**2**	**3**
I			
II			
III			
…			
m			
$J_{nap} = \sum Q \quad T_{nap}$	T_{nap}		

Figure 5.2 – Parallel method of building houses

The main advantage of the parallel construction method is the minimum construction time. However, the disadvantages of this method are much more significant. The following can be noted:

– A significant amount of equipment and labour required to implement the method ($\boldsymbol{R_{par} = rm}$);

– maximum consumption of resources of each type at any given time (high one-time demand for sets of earthmoving and transport machines, assembly cranes, building structures of a certain type, etc. required for the simultaneous construction of m houses);

– the type and range of resources consumed are constantly changing.

With the flow method for the construction of m buildings (Fig. 5.3), the technological process of construction of objects is divided into n component processes (different types of work), for example, the construction of foundations, the construction of walls and ceilings, the construction of roofs, finishing work, etc., for each of which the same duration is assigned, if possible, and the performance of these works is combined in time, thereby ensuring the sequential performance of the same type of work and the parallel performance of different types.

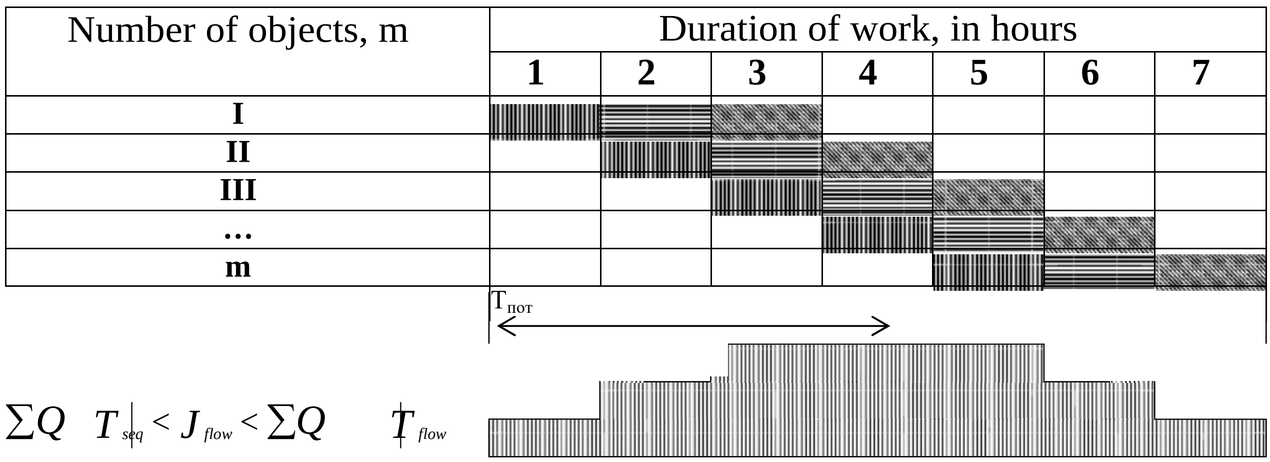


Figure 5.3 – The flow method of building houses

The flow method of construction requires less time than the sequential method (T_{flow} **<** $\boldsymbol{m}$*****T_s), and the maximum intensity of resource consumption is less than with the parallel method ($\boldsymbol{J}_{flow}$ **<** $\boldsymbol{J}_{par}$).

The division of the process of construction of buildings and structures into separate technological processes, specialisation of performers, different intensity of individual works and consumption of resources determine the mathematical dependencies between the operations of the production process, determining their quantitative characteristics and the size of production units.

Therefore, by establishing the regularities and quantitative dependencies that occur in construction processes, it is possible to increase the efficiency of construction production by using modern economic and mathematical methods and computers in the development of organizational and technological documents and design of the flow organization of production.

5.2 Basic principles of flow design

The task of designing the construction flow is to determine its parameters that, taking into account the rational technology and organization of work, ensure the construction of facilities within the standard duration, continuous loading of resources (teams, machines, mechanisms) and the continuity of construction and installation work on each facility. The construction flow is designed on the basis of data on the space-planning and design solutions of the facilities to be included in the flow by grouping similar buildings or parts for each type of building, taking into account the specialisation and number of teams, machines and mechanisms that can perform these types and volumes of work. The main objective of the flow calculation is to reduce the duration of construction, which would ensure the most productive use of workers and machinery by saturating the work front with the maximum amount of resources. In this case, all calculations should be based on the actual amount of resources that can be allocated by the relevant construction organizations to perform the scope of work in the flow.

Using the basic principles of the flow organization of industrial production and taking into account the peculiarities of construction production, the following principles and sequence of flow design for the construction of homogeneous construction objects have been developed:

– We install facilities that are to be built using the streaming method, i.e. similar in design, layout, number of storeys and technology.

– We divide the projected object into processes, preferably equal or multiple in terms of labour intensity.

– We establish an appropriate sequence of construction processes and combine interdependent processes into a common aggregate process. This division and synchronization of processes serves as a prerequisite for continuity, which is one of the most important factors in the advanced organization of production.

– We establish the sequence of inclusion of individual facilities in the construction flow, assign processes to certain teams of workers, establish the movement of teams at individual facilities during the technological process and from facility to facility, in accordance with the adopted sequence with minimal transitions.

– We equip teams of workers with construction machines, tools, and devices, which ensures high-performance execution of the processes assigned to the teams.

– We calculate the main indicators (parameters) of the flow.

– We design relocations from site to site in the established sequence, taking into account the observance of the set rhythm of work of the teams and the construction machines, tools and devices assigned to them.

5.3 Classification of construction flows

Construction flows are classified according to the following general features:

1) by the structure and type of product: private, specialised, object and complex.

A private flow is an elementary flow, which is one or more processes performed by one team (team or link) on private work fronts.

The products of a private flow can be excavation, foundation construction, wall masonry, plastering, etc. (Fig. 5.4, a)

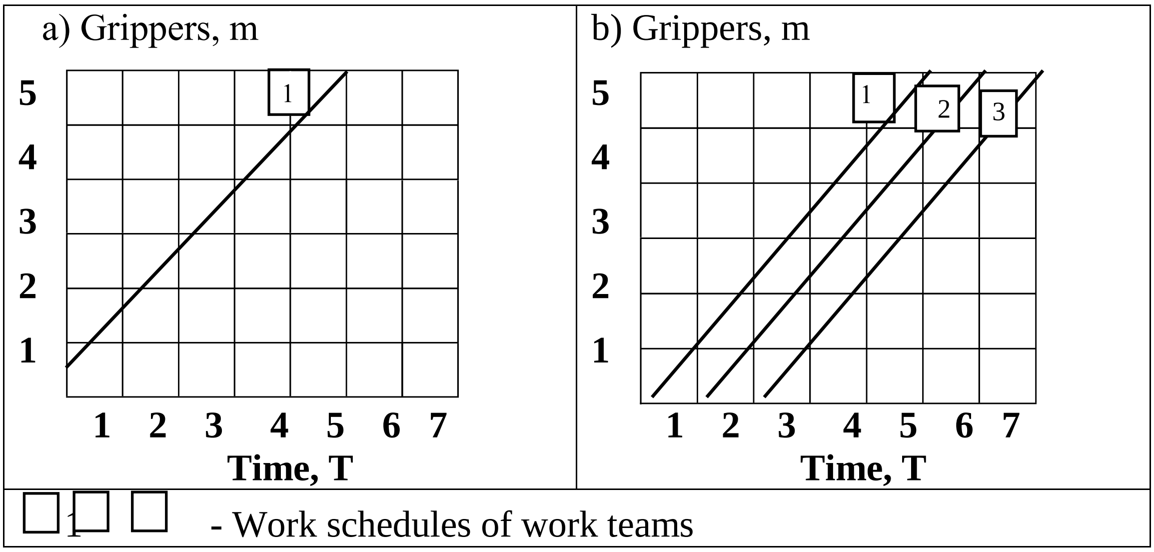


Figure 5.4 – Cyclograms of the general (a) and specialised (b) flow

A specialised flow is a set of technologically linked private flows united by a single system of parameters and flow diagram. Its products are a finished type of work, a structural element (grading, foundation, painting, etc.) or a part of a building (structure) (Fig. 5.4, b).

Private and specialised flows can have different directions of development. The direction of development of the flow depends on the space-planning and structural design of the building, the types of work performed and their stages, and the construction machines and mechanisms used. They can develop in a horizontal or vertical pattern. In this case, the flows of single-storey industrial buildings, as well as the flows of the zero cycle and roofing, are horizontal, the flows of erecting the box of a multi-storey building are horizontally ascending or vertically descending, and the flows of specialised finishing works are vertically ascending or vertically descending (Fig. 5.5).

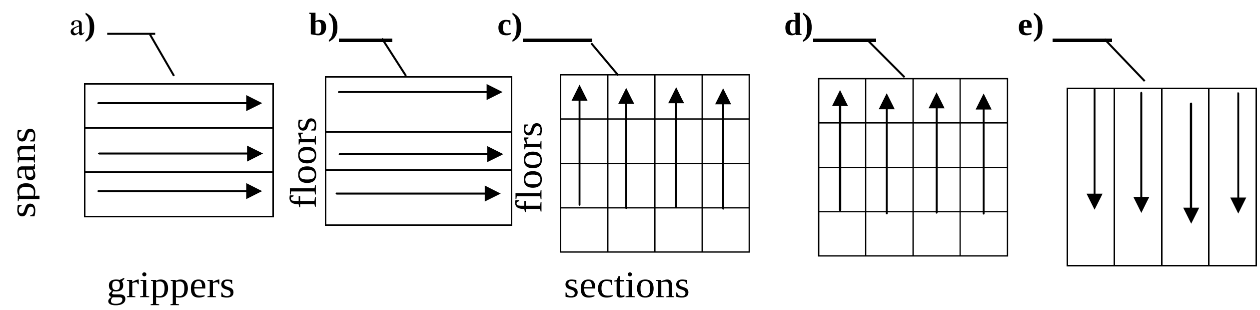


Figure 5.5 – Flow diagrams

Object flow – a set of technologically and organizationally linked specialised flows, the joint product of which is the construction of individual buildings (structures) or a group of homogeneous buildings (Fig. 5.6, a).

Complex flow – a set of organizationally linked object flows, the joint product of which is an industrial enterprise, residential area, etc. (Fig. 5.6, b).

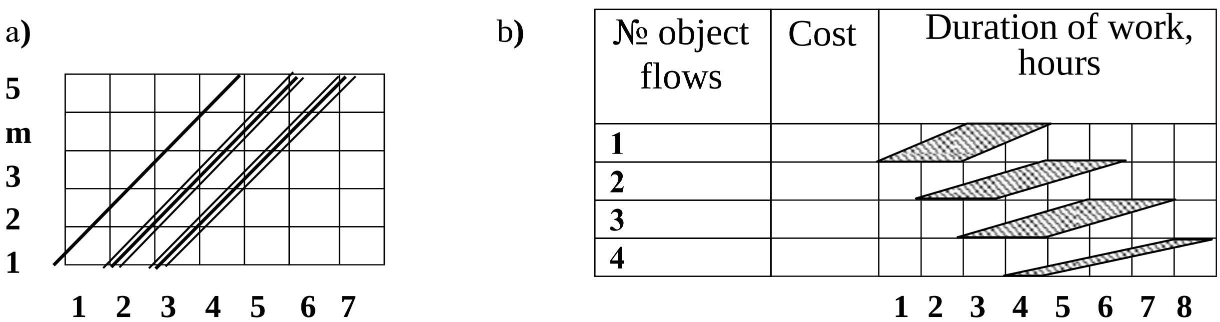


Figure 5.6 – Cyclograms of object (a) and complex (b) flows

A diagram of the technological structure and flow levels by type of work is shown in Fig. 5.7.

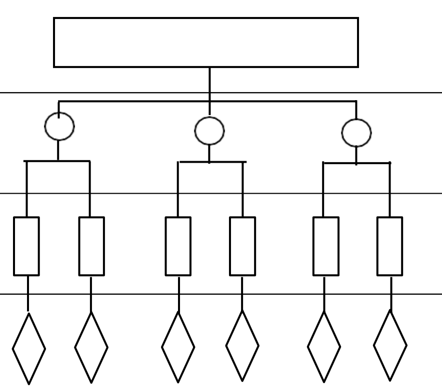
Flow type	Composition	Type of product
Comprehensive		Completed complexes of buildings structures): Industrial, enterprise, residential area.
Objective		Completed objects in the form of buildings and structures
Specialised		Completed work reports, designs, stages.
Private		Completed elements of works, auxiliary works

Figure 5.7 – Process flow diagram and flow levels

2) by the nature of rhythmicity: rhythmic and non-rhythmic flows.

Rhythmic – in which all components of the flow have a single rhythm, i.e. the same duration of work by each individual team on private work fronts.

A rhythmic flow is organised in the construction of homogeneous or identical objects, when all elements of the flow have a single pace for the development of all flow components.

Rhythmic flows are subdivided, depending on the duration of work on the grips (objects), into: a) equally rhythmic (i.e., having the same rhythms); b) multiple rhythmic (flows having multiple durations of work on the grips); c) different rhythmic (flows in which the rhythms of each team are constant, but not equal or multiple to each other; sometimes flows may have the same rhythms for the same type of work and different rhythms for different types).

Different rhythmic flows are used when designing an object flow for buildings that have the same amount of work on sections (tiers) (for example, a multi-storey residential building with a repeating floor plan, in which 1 - 2 floors are taken as a tier).

In construction practice, *even-rhythmic* and *multiple-rhythmic* flows are very rare, as the volume of construction and installation work, and therefore the duration of their execution, will vary significantly even for buildings with the same structural design.

Irregular flows - in which the duration of work performed by each individual team on private fronts is uneven.

Non-rhythmic, which are subdivided into streams with: a) homogeneous rhythm change (all specialised streams on homogeneous grippers (objects) have the same rhythms, and different grippers have different rhythms); b) heterogeneous rhythm change (the rhythms of all specialised streams on all grippers are different).

Irregular flows are designed for the construction of facilities with a complex configuration in plan, with different room heights and uneven distribution of work volumes in space. Such facilities are difficult to divide into sections (areas) that are equal in terms of labour (sections) that are equal in terms of labour intensity. Therefore, the duration of work on the sections by individual teams of constant size is different.

The most common is the non-rhythmic construction flow with a heterogeneous change in rhythm.

3) By the duration of operation: short-term, long-term and cross-cutting flows

Short-term - organised for the construction of individual buildings (structures) or groups of buildings, the construction duration of which does not exceed one year.

Long-term - organized during the construction of buildings or complexes of objects, the duration of construction of which exceeds one year. The organization of long-term flow construction is carried out with the aim of achieving for a long period (a year, two or more) uninterrupted loading of construction (assembly and commissioning) organizations, coordinated work of customers, project organizations, manufacturers and suppliers of materials, structures and equipment in the construction of homogeneous objects in sectors of the economy and various objects, the construction of which is carried out by territorial construction and assembly organizations, ensuring the implementation of production capacities in the established period.

Long-term flows contribute to the rhythmic operation of construction organizations and allow for a fuller use of construction equipment, labour and material resources. In addition, such flows create the conditions for the rhythmic operation of transport and production companies in the construction industry and help reduce the volume of construction in progress.

The end-to-end (continuous) flow includes the manufacture of structures, their transportation to the construction site and the process of building houses (for example, in the case of construction by a house-building plant).

The following construction flows are distinguished according to the technology of building construction:

- *without combining work* (with a sequential scheme);

- *with a combination of works* (with a parallel-serial scheme).

For construction flows without interconnecting activities, each subsequent activity can only start after the previous activity has been completed (see Fig. 5.8).

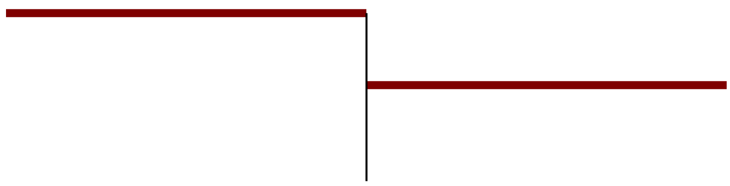


Figure 5.8 – Sequential workflow

In threads with a parallel-serial workflow, each subsequent work can begin before the previous work is completed (Fig. 5.9), usually in private threads. In practice, there are also threads that have a mixed scheme.

Figure 5.9 – Parallel and sequential workflow

According to the direction of development of private and specialised flows, we can distinguish:

– horizontal construction flows (see Fig.5.10); these include, for example, foundation laying, installation of structures for a one-storey industrial building, and roofing;

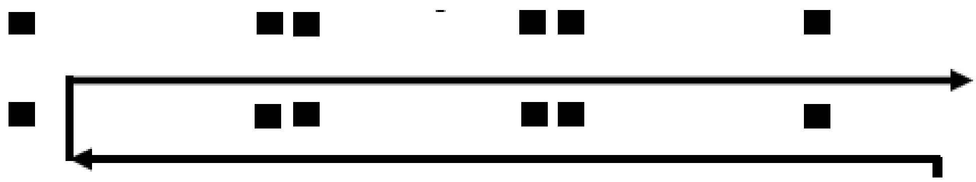


Figure 5.10 – Horizontal work flow diagram

– vertically ascending construction flows (e.g. sectional assembly of a building);

– vertically descending (finishing in a residential building, carried out "from top to bottom);

– inclined (brickwork on the floor, installation of structures on different grades);

– mixed.

From the point of view of the division of the production process and the division of labour between the workers involved in the flow, we distinguish between

– current-operational;

– current-divided;

– current-complex.

The flow-operational method is used in individual units. In this case, the production process between workers is divided by operations, for example, bricklaying is performed by a "three-man" team, where each of the three bricklayers is assigned to perform a specific operation (supplying mortar, spreading mortar, laying bricks).

The flow-divided method is a method in which individual team members perform simple processes in a specific area or section, for example, when installing a rolled roof, where the team members perform cement screed and sticker the rolled carpet.

The flow-complex method is used when complex processes are performed by complex teams, where the labour intensity of individual simple processes is different and team members have several related professions. For example, when concreting foundations, rebar work is usually less labour-intensive than concrete and formwork work, and rebar workers periodically switch to performing related work.

5.4 Parameters of construction flows

Construction flows are characterised by temporal, spatial, technological, static and dynamic parameters.

Temporary flow parameters include:

T – total duration of work on the flow as a whole;

T_1 – the total duration of all work on one gripper (flow deployment period);

T_2 – is the period of finished product release - the time equal to the duration of the work of the completion team (private, specialised or object flow);

t – flow step is the time interval after which the finished product (building, structure, completed parts thereof) is released from the flow or the time interval between the start of work of two neighbouring teams on the same grab (the period of inclusion of a private flow in the work), days

k is the crew's work rhythm - the duration of work on one grab (section, private work front) assigned to it, days;

T_{team} is the total duration of work of each team on all grippers;

t_{tech} – technological break between adjacent processes (a break caused by the requirements of the technical specifications for the work, the nature and properties of the materials used, for example, concrete hardening, drying of plaster, etc;)

t_{org} – organizational break (a break caused by the need to move workers or prepare the work front for the next process);

t_c is the period of flow curtailment (the time interval during which teams are gradually excluded from work).

The spatial parameters of the flow include: work front, grab, site, object (building or structure), m.

A grab is a part of a building or its structural element within which private flows that are part of a specialised flow develop and coordinate with each other. The scope of work on a section is carried out by a permanent team with a certain rhythm, which ensures the flow organization of the construction of the facility as a whole.

The building is divided into sections to ensure the necessary stability in the conditions of independent work within the section. For example, if the boundaries of a section coincide with temperature or settlement seams, it is possible to stop and resume work without violating the technical conditions. Minimum gripper sizes are determined by the variable productivity of the unit or specialised team. The number of grippers that can be divided into a plan is determined by the space-planning and design features of the building, and also depends on organizational considerations. Repeated spans, sections, floors and structural volumes along a certain group of building axes, etc. are used as captures. When designing a complex flow, individual objects are often used as captures.

A site is a part of a building under construction within which interdependent specialised flows that are part of the object flow develop. The site is a spatial structural and technological part of the building, during the construction of which the entire complex of construction, installation and special works is repeated.

Front of work is a part of a construction project that is necessary and sufficient to accommodate workers together with the machines, mechanisms and devices required for the work.

Tier is a part of an object formed by its conditional vertical division. The number of tiers is determined by the architectural and structural design of the building (column with 1 or 2 floors), depends on the technical conditions for the work (height of the embankment layer when constructing earthen dams and dams), the parameters of the construction machines used (height of the excavation when digging a pit) and may be dictated by the convenience of the work (for example, in brickwork).

The technological parameters of a stream include the number of private, specialised or object streams (n), the volume and labour intensity of work, and the intensity (capacity) of the stream.

Two types of teams have been formed in the organization of stream construction – specialised and integrated.

Specialised teams can be ordinary and complex specialised. An ordinary team performs one type of specialised work (plastering, painting, sanitary, electrical, etc.). A complex specialised team performs two or more types of specialised work of a technologically similar profile (painting, wallpapering and linoleum flooring or plastering and facing works, etc.).

An integrated team performs a range of technologically interrelated general construction works. For example, an integrated team of bricklayers performs brickwork, installation of reinforced concrete floors and staircases, installation of window and door units, etc.

Flow intensity (capacity) is the amount of output in physical terms produced by a construction flow per unit of time. For example, the number of square metres of total housing area per day. For private and specialised flows, the flow intensity can be the number of cubic metres of concrete poured per day, the number of square metres of plastered surface, etc.; for the flow as a whole, this indicator can be the number of square metres of residential, useful or industrial space, cubic metres of a building, determined conditionally during the construction process per day, depending on the degree of completion of the object.

Static parameters are initial and do not depend on production conditions. They include: the volume of work V_i, the labour intensity of work A_i and the cost of work C_i performed by private or specialised streams.

Dynamic parameters are determined by specific production conditions. They include: the number of workers R_i, the output per worker per day in value terms B_i, and the intensity of the flow in natural terms I_i.

5.5 Basic laws, technological linkage and calculation of construction flow parameters

The technological linkage of flows is performed based on the following assumptions:

– work on each subsequent gripper is started at an interval equal to the flow step;

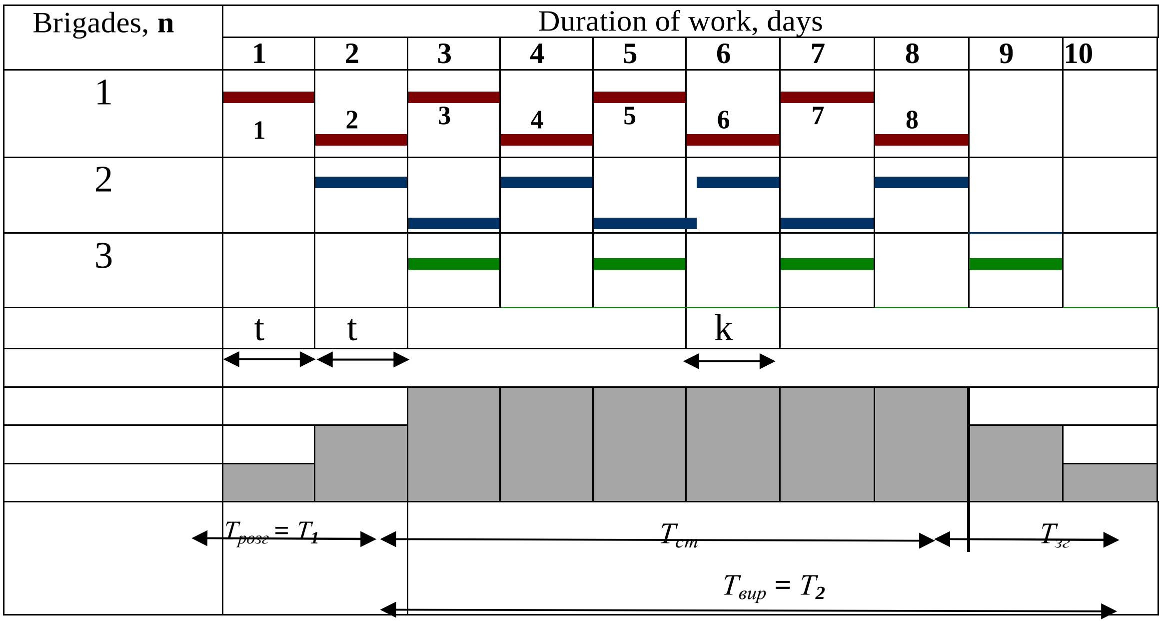
– one team (link) or several teams can work on one gripper with the same rhythm;

The size of each gripper remains the same for all types of work performed on the grippers.

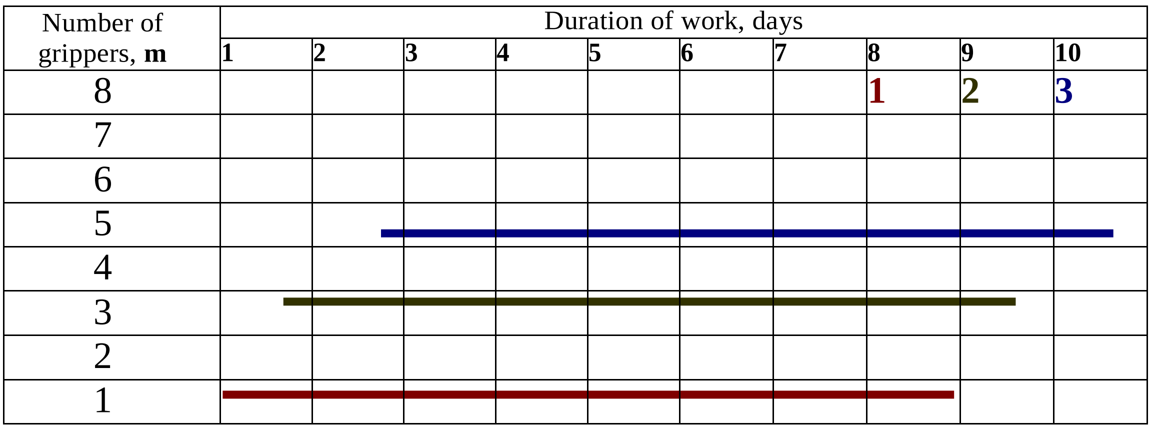
After completion of the entire complex of works on one gripper, work on each of the following grippers shall be completed no later than at an interval equal to the flow step.

5.5.1 Calculation of rhythmic flow parameters

To establish the basic laws and methods of technological linking of rhythmic construction flows, we will introduce the following notations (Fig. 5.11) in addition to those already discussed in Section 4.



Rhythmic flow - a linear calendar graph by H.L. Gantt (1890)



Budnikov's cyclogram (1935)

Figure 5.11 – Technological linking of the rhythmic flow

m – the number of private work fronts (grips, sections or objects), pcs;

n – the number of processes performed in the flow or the number of types of work, respectively, the number of teams (links), pcs.

Using these concepts and notations, the duration of the rhythmic flow can be expressed by the following formulas:

$$T = T_1 + T_2\,; \tag{5.3}$$

$$T_1 = (n - 1)t\,; \tag{5.4}$$

$$T_2 = m*k\,. \tag{5.5}$$

in the rhythmic flow $t = k$. Then

$$T=(n-1)1+m*t=(m+n-1)t, \tag{5.6}$$

Depending on the nature of the initial data, different flow parameters can be calculated using formula (5.6). For example, given the total construction duration (T) and the known number of crews (n) and grippers (m), the flow step size

$$t=T/(m+n-1). \tag{5.7}$$

Number of teams for a given T and accepted ***t*** and ***m***

$$n= T/t + 1 - m, \tag{5.8}$$

Number of grippers

$$m = T/t + 1 - n. \tag{5.9}$$

When designing flows, possible technological (tech) and organizational (org) breaks are also taken into account. If the next work on the gripper can be performed only after a certain break due to the work technology, for example, curing a concrete structure before it is shuttered, drying plaster before painting, etc., then there is a need for technological breaks.

Organizational breaks arise in a number of cases due to labour protection conditions, etc.

If these breaks are not taken into account in the flow step duration, their values are included in the calculation formula for the total flow duration, i.e.

$$T=(m+n-1)t+\sum t_{тех}+\sum t_{орг}. \tag{5.10}$$

Construction flows can be represented graphically in the form of a linear calendar schedule by G.L. Gantt (1890) or a cyclogram by M.S. Budnikov (1935). On a linear graph, the share of each specialised flow team is highlighted by a horizontal bar, and the period of work of such a team at different grippers is shown by segments offset from each other (Fig. 5.11).

The cyclogram retains the calendar scale of the line graph. However, a horizontal bar is allocated for the grippers in the order of their numbers from bottom to top. Therefore, the work of each team is depicted by an inclined line, which symbolises the movement of each team along the front of the work of one shovel and the transition of teams from one shovel to another.

Three periods can be distinguished in the development of the construction flow within an object or complex (see Figure 5.11):

- the period of flow deployment (T_{dep}=T_1), when teams and necessary machines are successively included in the flow at intervals equal to its rhythm;

- Steady-state flow period (T_{st}), which corresponds to a constant and maximum number of workers;

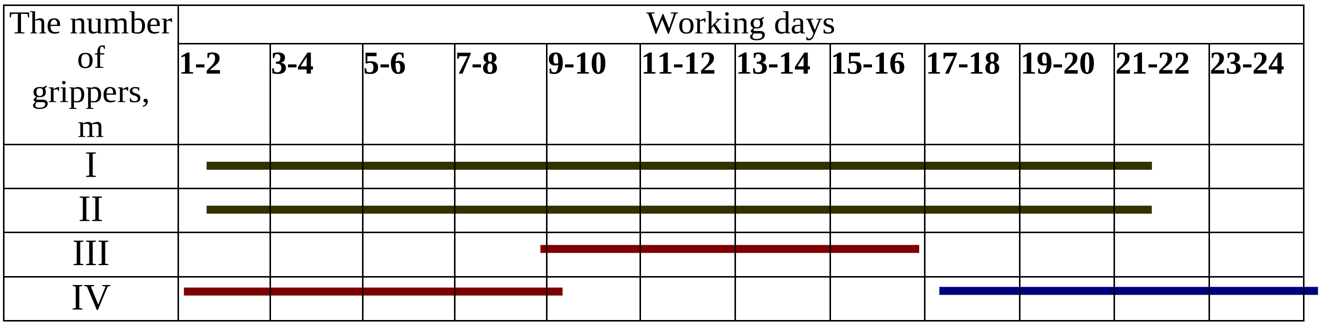
- flow curtailment period (T_{cf}), when teams (links) of workers are successively excluded from the flow at intervals equal to its rhythm.

5.5.2 Calculation of parameters of differently rhythmic flows

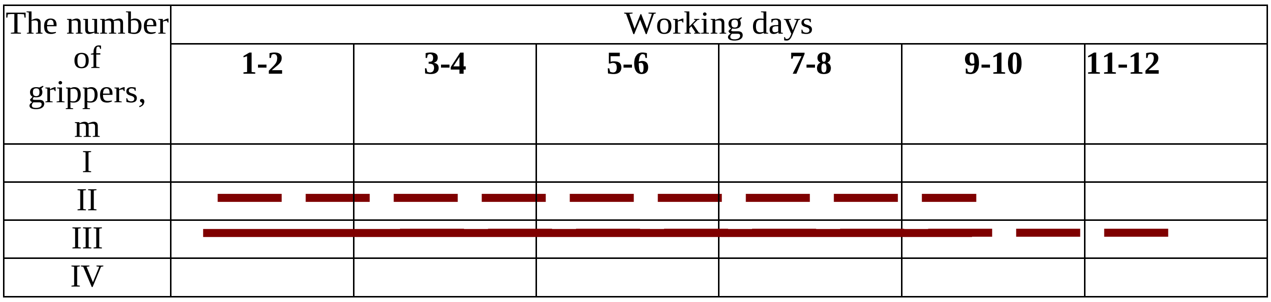
In differently rhythmic flows, for some processes, the same rhythm of work of teams can be adopted, equal to a certain number of days, while for others, due to the increased labour intensity of work, rhythms should be adopted several times longer.

For example, in Fig. 5.12, a shows a cyclogram of a specialised flow for the construction of the underground part of a building. The rhythm of the first team for excavation and the third team for waterproofing the foundation walls and backfilling the foundation sinuses with soil is 2 days, and the rhythm of the second team for concrete foundation is 5 days.

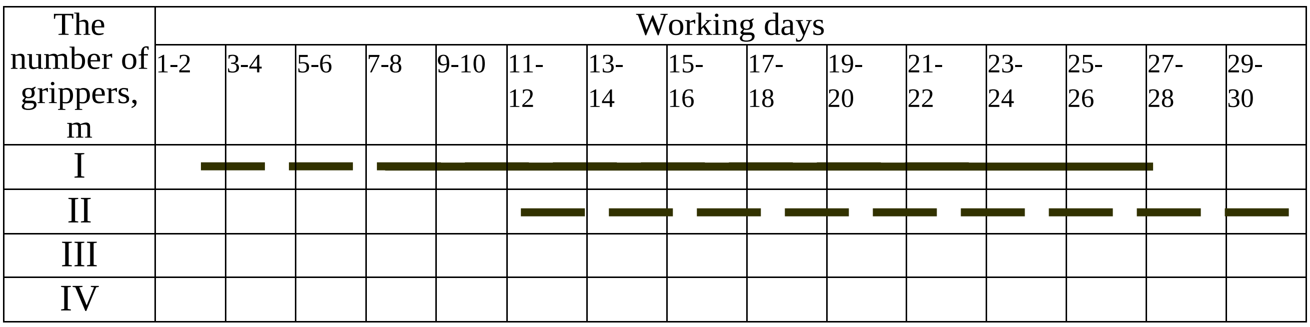
The technological linkage of the work of the teams in the considered multi-rhythmic flow is performed as follows. The second team, since its work rhythm is greater than the rhythm of the previous team, is included in the work immediately after the first team releases the first gripper (Fig. 5.12, a). The third team, whose work rhythm is less than the rhythm of the previous team, is included in the work after the second team approaches the last gripper (see Fig. 5.12, a). This is due to the fact that only in this case the third team will not be idle, waiting for the front of the work.



a) Number of brigades n = 3 (rhythm of work of 1 brigade k_1 = 2 days, 2 brigades k_2 = 5 days, the third brigade k_3 = 2 days); number of grippers m = 4



b) Variant at t = k_i = 2 days; number of grippers m = 4



c) Variant at t = k_i = 5 days; number of grips m = 4

Figure 5.12 – Cyclogram of a multi-rhythmic flow and options for converting it into rhythmic flows

When operating differently rhythmic streams, in order to keep the grippers from being idle, it is necessary to increase the number of workers in the teams with the highest rhythm, and thereby equalise the rhythms with the lowest (in Fig. 5.12,b – 2 days) But this is not always possible for various reasons: a small work front, limited crane productivity, etc.

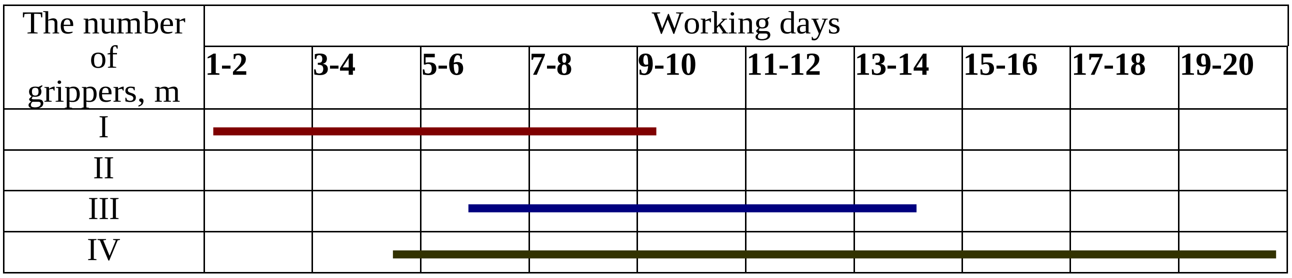
In order to exclude empty grippers, it is possible to organise a flow with the same rhythms of the teams, taking the longest rhythm as a basis (in Fig. 5.12,c – 5 days).

However, one of the disadvantages of such flows remains - an unreasonably long duration of work.

These disadvantages can be avoided when designing flows by striving to ensure that the values of the rhythms of the teams' work are multiples of each other.

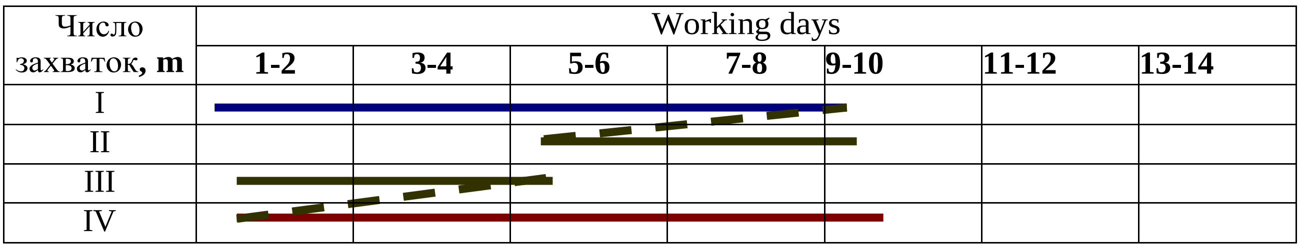
After that, several teams are assigned to perform processes with lengthening rhythms. For example, if the rhythm multiplicity is two, two teams are assigned to perform one production process; if the rhythm multiplicity is three, three teams are assigned, etc.

In Fig. 5.13, a shows a stream whose rhythm is a multiple of two.



T=20

a) Number of brigades n=3 (rhythm of work of 1 and 3 brigades $k_1 = k_3 = 2$ days, 2 brigades $k_2 = 4$ days); number of grippers m=4



T=(4+4-1)*2=12 days

б) Number of brigades n=4 (rhythm of work of 1 and 3 brigades $k_1 = k_3 = 2$ days, brigade 2a $k_{2a} = 2$ days, brigade 2b $k_{2b} = 2$ days); number of grippers m = 4

Figure 5.13 – Cyclogram of a multi-rhythmic flow and options for converting it into rhythmic flows

In a specialised flow (Fig. 5.13, b), the first and third teams work with a rhythm of 2 days, and the second team works with a rhythm of 4 days, i.e. a multiple of 2 days.

Then we organise two parallel parts of the flow - 2a and 2b - performing the same processes, one of which (2a) develops on odd grippers, and the other (2b) - on even grippers.

Technological linking of such streams is also quite simple - teams are included in the work as the corresponding grippers of the previous one are released.

5.5 Calculation of flow parameters using matrices

The flow parameters considered in paragraphs 3.5.1 - 3.5.2, such as the duration of the flow and its constituent private flows, the periods (time) of their inclusion in the work, the order of work of teams on the sections or objects, as well as the degree of interconnection of work on all sections, should be calculated using matrices.

A matrix (mathematical concept) is a rectangular table with intersecting rows and columns. In the places where they intersect (i.e., in the cells), the initial information is recorded and mathematical operations are performed.

Let's look at the specifics of calculating and optimising flows using matrices using specific examples.

Let's consider the parameters of a variable-rhythm flow using the example of a flow whose information is given in the following source table (Table 3.1).

Table 5.1 – Initial data on the work of 4 teams on 4 grippers

Number of grippers, t	Brigade number, i			
	1	**2**	**3**	**4**
I	1	3	2	1
II	1	3	2	1
III	1	3	2	1
IV	1	3	2	1

Calculate the duration and all other flow parameters using matrices as follows. In the middle of the cells of the matrix shown in Fig. 5.16, we write down the duration of the work of the teams on the grippers.

The calculation is performed in the following sequence. First, at the end of each column, we put the duration of the work of the teams $\sum k_i$, for which we sum up the duration of work on all grippers. For example, for the 1st team, this duration is 4 hours, for the 2nd team - 12 hours, etc.

Then, in the upper left corner of the first cell, enter the start time of the 1st team on the 1st gripper (usually zero is taken as the start of the countdown), and in the lower right corner, enter the end time of the team, which is equal to the start time plus its duration.

The end time of the work on the 1st gripper is considered the beginning of the work of this team on the 2nd gripper, so this time is transferred without changes to the upper left corner of the second cell of the same column (see Fig. 5.14).

Number of grippers, t	Brigade number, i			
	1	2	3	4
I	0 1 1	1 3 4	7 2 9	12 1 13
II	1 1 2	4 3 7	9 2 11	13 1 14
III	2 1 3	7 3 10	11 2 13	14 1 15
IV	3 1 4	10 3 13	13 2 15	15 1 16
	4	12	8	4

Figure 5.14 – Calculation of the differently rhythmic flow using the matrix

Summing this time with the duration of work on the second gripper, we determine the end time. This time is recorded in the lower right corner of the second cell.

Thus, we calculate the start and end of work on all the grippers of the 1st brigade. Further calculations by columns are performed depending on the duration of the work of the teams. If the duration of the next team is longer than the duration of the previous one, then the calculation is carried out from top to bottom, and if it is less, then from bottom to top.

From Fig. 5.16 shows that the total duration of the 2nd team's work is longer than the duration of the 1st team's work (12>4), so we start calculating the start and end of the 2nd team's work on the grippers from the top down, i.e. from the moment when the I-th gripper is released.

To do this, from the bottom corner of the first cell of the first column, we transfer the time characterising the end of work on the I gripper to the upper left corner of the first cell of the second column. Next, we calculate the second column similar to the previous one.

Since the duration of the 3rd crew is less than the duration of the 2nd crew (8<12), we calculate the start and end of the 3rd crew from the bottom up. To do this, first, in the left corner of the last cell of the third column, we transfer the time when the 2nd team finished work on the last gripper. At the same time, this time is transferred to the lower right corner of the overlying cell, where this time corresponds to the end of the 3rd team's work on the previous gripper.

The start of the team's work on this gripper is defined as the difference between this time and the duration of the team's work on the gripper. Fill in all the cells of the matrix in the same way.

The number in the bottom corner of the last cell of the matrix shows the total duration of the work.

In the example above, it is equal to 16 units of time. After calculating the flow parameters using the matrix, we build a flow cyclogram for the same example to illustrate the flow (Fig. 5.15).

The calculation of parameters of non-rhythmic flows using matrices is similar to the calculation of differently rhythmic flows, except that in the process of calculations it is necessary to determine for each pair of adjacent teams the place of their critical convergence, which, unlike differently rhythmic flows, can be located on any gripper.

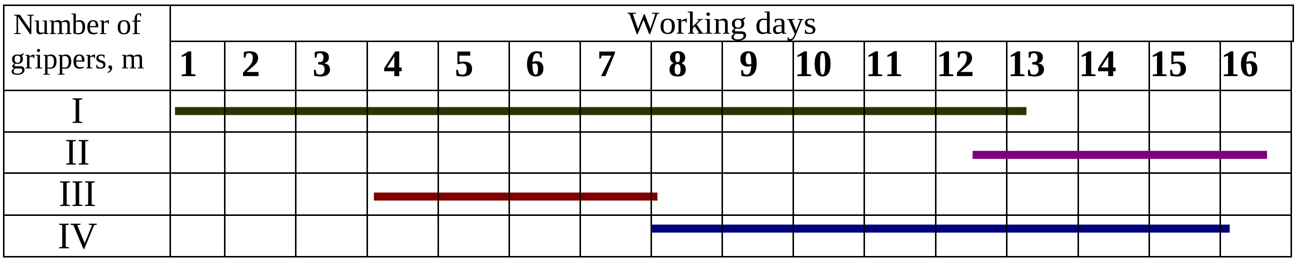


Figure 5.15 – Cyclogram of a non-rhythmic flow calculated using a matrix

Let's calculate, for example, the parameters of an irregular flow, information about which is presented in the matrix (Fig. 5.16). At the first stage of the calculation, we determine the critical convergence points of each pair of adjacent teams (flow shares).

To do this, we find the maximum duration of work on the by these two crews by summing up the duration of their work on the grippers, provided that the critical convergence is first on the 1, then on the 2, etc. gripper. The results of the summation (according to the scheme shown in Fig. 5.18) are written in the last lower row of the matrix in the form of columns (see Fig. 5.17).

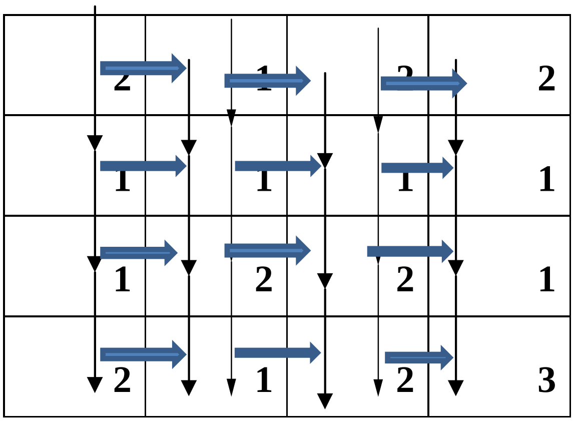


Figure 5.16 – Matrix with information of irregular flow

For example, for the 1st and 2nd brigades, these durations are equal to the following values, provided that the critical convergence is in place:

on the I grip -2 + 1 + 1+2+1 = 7;

on the II grip - 2 + 1 + 1 + 2 + 1 = 7;

on the III grip - 2+1 + 1+2 + 1 = 7;

at the IV grip - 2+1 + 1+2 + 1 = 7.

All the values of the sums are the same. This means that the critical convergence of the two teams in question is at all four grippers. Similarly, we find the places of critical convergence of all other pairs of teams.

Number of grippers.	Number of brigade				$\sum k_j$	$\sum$	$\sum k_j + \sum t_{пер.j}$
	1	2	3	4			
I	0 **2** 2	2 0 **1** 3	3 0 **2** 5	5 0 **2**	7	0	7
II	2 **1** 3	3 0 **1** 4	5 1 **1** 6	7 1 **1** 8	4	2	6
III	3 **1** 4	4 0 **2** 6	6 0 **2** 8	8 0 **1**	6	0	6
IV	4 **2** 6	6 0 **1** 7	8 1 **1** 9	9 0 **3**	7	1	8
$\sum k_i$	**6**	**5**	**6**	**7**	24	3	27
$\sum t_{пер.i}$	0	2	1				
	7	7	9				
	7	6	8				
	7	7	9				
	7	6	9				

$C = \sum k_j / (\sum k_i +$

Figure 5.17 – Calculation of irregular flow using the matrix

For the 2nd and 3rd brigades we find: on the I grip 1+2+1+2+1=7; on the II grip - 1+1+1+2+1=6; on the III grip - 1+1+2+2+1=7; on the 4th grip - 1+1+2+1+1=6. The largest value of the sums is 7. This means that the critical convergence of the 2nd and 3rd brigades is at the I and III grips.

For the 3rd and 4th brigades, respectively, we find on the I grip -2+2+1+1+3=9; on the II grip -2+1+1+1+3=8; on the III grip - 2+1+2+1+3=9; on the IV grip 2+1+2+1+3=9.

The largest value of the sums is 9 in 3 cases. This means that the critical convergence of the 3rd and 4th brigades is at the I, III and IV grips After determining the locations of critical convergences, the calculation begins with those matrix cells where the critical convergence is set. The calculation itself is similar to the one discussed above for a differently rhythmic flow.

The cyclogram of the non-rhythmic flow, calculated using the matrix, is shown in Fig. 5.18.

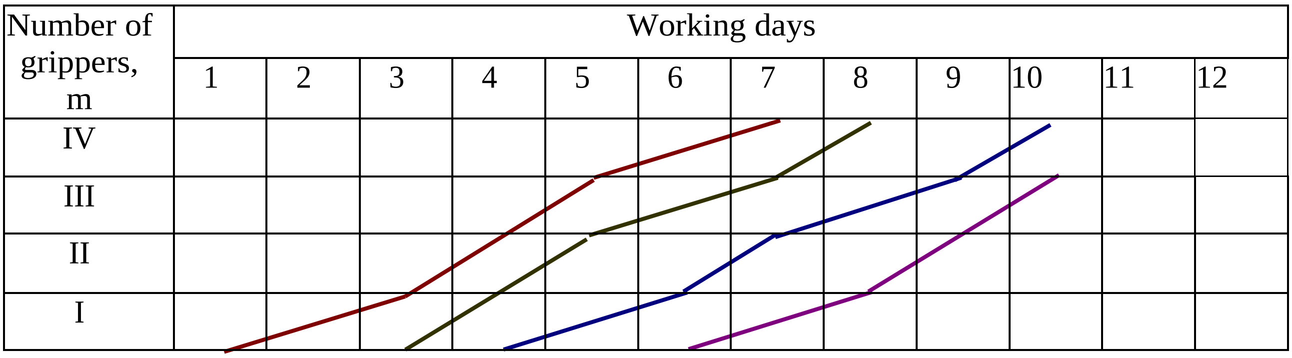


Figure 5.18 – Cyclogram of the irregular flow calculated using the matrix

The quality of the designed flows is assessed using various criteria, including: flow duration; degree of interconnectivity of activities; and level of uniformity of the construction flow.

Questions for self-testing:

1. What is the essence of the flow organization of construction production?
2. What are the basic principles of flow design?
3. Give a classification of construction flows.
4. Name the parameters of construction flows.
5. What are the main patterns and technological linkage of construction flows?
6. Calculate the parameters of the rhythmic flow.
7. What are the distinctive features of the flow method in comparison with the sequential and parallel methods of work organization?
8. Name the main advantages of the flow method.
9. Name the names of scientists who have contributed to the theory of streaming construction.
10. List the main stages of construction flow design.

TOPIC 6 NETWORK MODELLING OF CONSTRUCTION PRODUCTION

Questions for theoretical preparation

6.1 Organizational and technological models of construction production.

6.2 Purpose of network models and network graphs.

6.3 Classification of network models and elements of network graphs.

6.4 Network models.

6.5 Calculation of the network graph "vertices - works".

6.6 Calculation of the network graph "nodes-events".

6.7 Calculation algorithm directly on the network graph

6.1 Organizational and technological models of construction production

Construction production is a complex organizational and technological system, which can be presented in the form of a model to facilitate its study.

A model in the broadest sense is any simplified image, sample or analogue of any complex object, process or phenomenon (the "original" of this model) used as its "representative". The concept of a model is associated with a certain similarity between two objects. In addition to similarity, a model must meet a number of requirements:

1) reflecting only the essential relationships;

2) visibility;

3) clarity of the language used and not too much complexity.

The process of research on models that properly represent the system under study is called modelling.

Modelling of construction production is the study of construction processes by building and studying their models, which is a simplified representation of a certain object, more convenient for perception than the object itself.

In organizational and technological models of construction, the performance of certain types of construction work, the timing and intensity of work, and the rational use of resources.

The construction process and type of work can be represented in the form of an imaginary descriptive or graphical model.

There are various types of organizational and technological models of facility construction, and in some cases it is possible to identify the most rational areas of application for each of them. The following graphical models of construction production are used: linear (tape) graphs by G.L. Gantt, cyclograms by M.S. Budnikov, tables (matrices), and network graphs.

The most commonly used line graphs can be used to clearly show the unambiguous relationship and sequence of work. However, such diagrams are not very effective when there are complex dependencies between activities.

The cyclogram clearly shows the development of the construction process in time and space. It is most convenient for the construction of similar buildings and structures. In this case, the unit of production is most often a plot or a grab. A section of a multi-storey residential building is usually a typical section within one floor.

In the construction of large industrial complexes, which are characterised by complex interconnections of works, the visibility of the cyclogram is reduced and it is inconvenient to use.

When using matrix models, it is easy to determine the duration of work performed by each team, the total duration of construction, the downtime of teams at the fronts of work, and the level of work combination.

In Lecture 3, three organizational and technological models (linear, cyclograms, matrices) were discussed in detail.

Network models make it possible to best reflect the order of construction of a complex facility, implement scientifically sound construction methods, and identify and resolve many problematic situations that arise in the course of construction work.

The network schedule is a document that allows you to quickly manage construction and reallocate resources depending on the actual state of construction. It has a number of other advantages over other models.

However, the use of network diagrams does not mean that the use of line graphs, cyclograms and matrices is excluded.

These models complement each other and are used where they are most appropriate.

Network schedules are *most appropriate* for the construction of complex industrial and other complexes involving many organizations, and network schedules take into account all the work on which the successful progress of construction depends, including design, external supplies of materials, process equipment, etc.

6.2 Purpose of network models and network schedules

Network models are used in construction to solve the problems of long-term planning, determine the duration and timing of the main stages of facility creation (design, construction and installation works, supply of technological equipment, development of production capacity), as well as planning capital investments by periods of facility construction.

Network models are also used to solve the problems of operational planning of construction production for a single object, building, or structure. In 1956, the American company DuPont de Nemours created a group to develop methods and tools for construction management. In 1957, the UNIVAS research centre and the Remington Rand company joined this work. By the end of 1957, this team, led by D. Kelley and M. Vaiker, with the participation of mathematician D. Malcolm, developed the Critical Path Method (CPM - Critical Path Method) with a computer implementation. The CPM was tested at the construction of a chemical fibre plant in Louisville, Kentucky.

Following the CPM (- Critical Path Method), the US Navy's Polaris programme developed and tested a network planning system, the Programme Evolution and Review Technique (PERT), in 1957-1958.) The Polaris programme included 250 contractor firms and more than 9,000 subcontractor firms.

Since 1958, CPM and PERT have been used for work planning, risk assessment, cost control and resource management at a number of large military and civilian facilities in the United States, and then these methods began to be applied worldwide. In the Soviet Union, the critical path method was introduced in construction in 1962-1963.

Network diagrams owe their development to graph theory, which is one of the branches of topology, i.e. the science that studies the properties of geometric images. The first work on graph theory belongs to academician L. Euler. In 1736, L. Euler proved the unsolvability of a problem that fascinated the inhabitants of the city of N. Its essence was as follows. There are 7 bridges on the Pregel River, which washes around two islets. Can any citizen, starting a detour from a certain point A, cross each bridge once and return to the starting point A. Thus, initially, graph theory dealt mainly with mathematical entertainment and puzzles. In recent years, graph theory has literally captured the imagination of representatives of various specialties: communications specialists, electricians, chemists, economists, biologists, builders, etc.

In network modelling of construction production, two concepts are used: network models and network graphs.

6.3 Classification of network models and elements of network graphs

Network models can be different depending on the nature of the construction object, goals and a number of other indicators.

Network models are classified according to the following criteria:

1) *By the type of goals* - single-purpose models and multi-purpose models (for example, in the construction of various facilities being built by one construction organization;

2) *By the number of objects covered*: private model and complex model

(for example, for one facility and for the entire industrial complex of a plant);

3) *By the nature of the estimates* of model parameters: deterministic (with predetermined and fully determined data) and probabilistic (taking into account the influence of random factors);

4) *models based on target orientation* (time, resource, cost).

In the following paragraphs, we will consider simple models: deterministic, single-objective, private and complex time-based models.

The elements of a network graph are (for the node-event type):

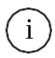
- *work* - a process that requires time and resources (for example, digging pits, concreting foundations, installing columns, etc;)

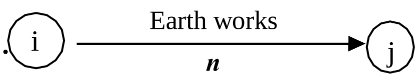
- *event* - the fact of completion of one or more works necessary and sufficient for the commencement of one or more further works that do not require any time or resources (e.g., completion of digging pits, concreting foundations, roofing, etc.);

- *waiting* - a technological and organizational break between works that requires only time (e.g., concrete hardening, plaster drying, etc.)

- *dependency* (or fictitious work) - an element of the network schedule that is introduced to reflect the correct technological relationship between works that do not require either time or labour costs (such as the completion of trenching at the 1st grab and the possibility of starting to lay foundation blocks at the same grab);

The following notations are used for the network graph elements: work and waiting are represented by solid lines with arrows pointing in the direction of the technological process (from left to right); an event is represented by a circle, and a dependency is represented by a dotted line with arrows.

Events are numbered with one number 

and works are numbered with two (the numbers of the previous and subsequent event s). 

The length of the lines with arrows can be arbitrary, but sometimes the network graph is drawn on a time scale, i.e., tied to calendar days of work.

The name of the activity is indicated above the arrow, and the duration of the activity (n) is indicated below the arrow. To make it easier to remember the characteristics of the elements of the network schedule, we present Table 6.1.

Table 6.1 - Network diagram symbols and time and resource requirements.

Elements of a network graph	Symbols and notation	Expenses	
		time	resources
1. Work	⟶	+	+
2. Event	(i)	-	-
3. Waiting	⟶	+	-
4. Dependence (fictitious work)	- - - - - - - - - - →	-	-

6.4 Network models

The main method for solving planning and management tasks in construction is the network planning and management (NPM) method. The NPM method includes the construction, calculation, analysis and optimisation of network models and is used to solve problems related to the planning and management of construction.

The NPM method combines automated accounting and control, selection and management decision-making. The results of the network model calculation contain an assessment of the performance of work to achieve the goal. This allows managers to focus on the issues that currently affect the timing of achieving the goal. Based on information about time, volume and resource parameters, regulatory options are modelled and the most rational one is applied. A network model is used as a model of the production process.

A network model with the required level of detail reflects the interconnection of individual works on the construction of an object (complex) and makes it possible to carry out a mathematical analysis of the schedule, predict its future state, and evaluate the effectiveness of decisions.

A network model is an oriented graph that reflects the sequence and organizational and technological relationships between the activities that are required to achieve the goal.

A network model represented graphically on a plane with calculated time and resource parameters is called a network graph. Network graphs are used to calculate time parameters and optimise schedules.

6.4.1. Rules for creating network schedules

To build a network schedule, it is necessary to identify the sequence and interconnection of activities: what activities need to be performed, what conditions need to be met to enable this activity to begin, what activities can and should be performed in parallel with this activity, and what activities can be started after this activity is completed. These questions allow you to identify the technological relationship between individual activities, ensure the logical construction of the network schedule and its compliance with the modelled set of activities.

The level of detail of the network schedule depends on the complexity of the facility, the amount of resources used, the scope of work and the duration of construction.

There are two types of network schedules:

- node-work;
- node-events.

6.4.2. Network graphs of the "node-work" type

The elements of such a graph are activities and dependencies. A job is a specific production process that requires time and resources to complete and is represented by a rectangle. A dependency (dummy job) shows an organizational and technological connection between jobs that does not require time and resources and is represented by an arrow. If there is an organizational or technological break between activities, the dependency indicates the duration of this break. An example of a node-job network graph is shown in Fig. 6.1.

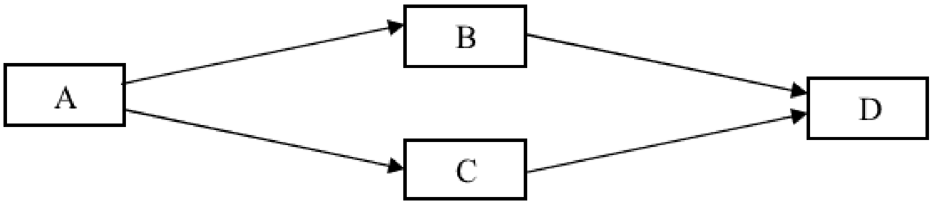


Figure 6.1 – A network graph of the "nodes-work" type.

If a node-work activity has no previous activities, it is the start activity of the network graph. If a job has no subsequent jobs, it is the final job of the network schedule. There should be no closed loops (cycles) in the node-job network graph, i.e. dependencies should not return to the job from which they came.

6.4.3. Network graphs of the "node-event" type

The elements of this type of graphs are activities, dependencies and events. A work is represented by a solid arrow, a dependency by a dotted arrow. An event is the result of one or more activities that are necessary and sufficient to start one or more subsequent activities and is represented by a circle. In network graphs of this type, each activity is located between two events: the initial event from which it leaves and the final event to which it enters. The events in a network graph are numbered, so each activity has a code if it consists of the numbers of its start and end events. For example, in Fig. 6.2, the activities are coded as (1,2); (2,3); (2,4); (4,5).

If an event of a node-event network graph has no preceding activities, it is the ascending event of this graph. The activities immediately following it are called initial activities. If an event has no subsequent activities, it is called a final event. The activities that are part of it are called completion activities.

To correctly display the relationships between activities, you must adhere to the following rules for constructing a node-event network graph:

1. When depicting simultaneous or parallel activities (for example, activities "B" and "C" in Fig. 6.2), a dependency (3,4) and an additional event (3) are introduced.

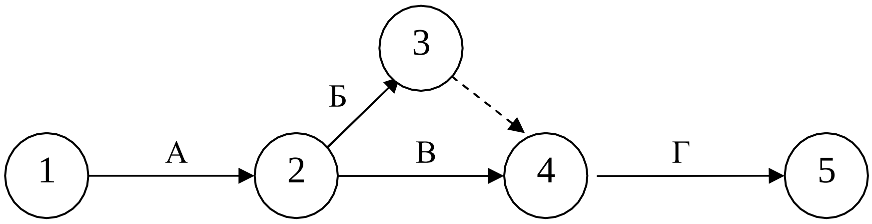


Figure 6.2 – Network graph of the "nodes-jobs" type.

2. If for the start of work "D" it is necessary to perform work "A" and "B", and for the start of work "C" - only work "A", then a dependency and an additional event are introduced (Fig. 6.3).

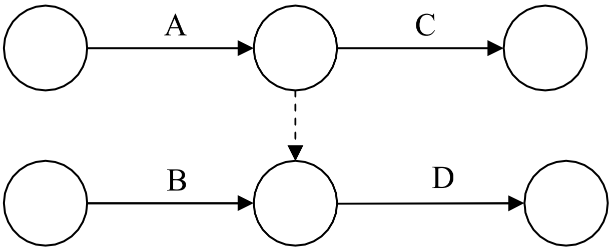


Figure 6.3 – Depiction of the dependency between works.

3. The network graph should not contain closed loops (cycles), i.e. a chain of activities that returns to the event from which they originated (Fig. 6.4).

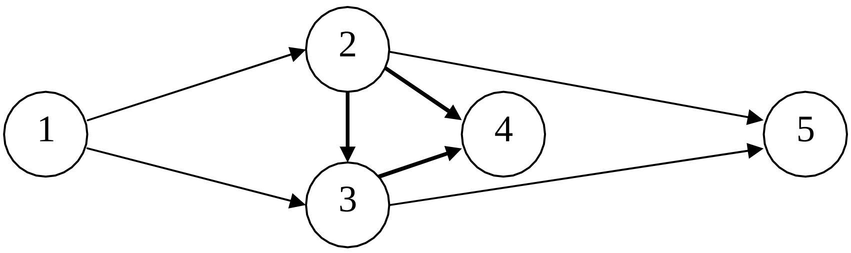


Figure 6.4 – An example of a closed loop (2, 4, 3, 2)

4. Additional events and dependencies are introduced in the network schedule for the flow organization of construction (Fig. 6.5)

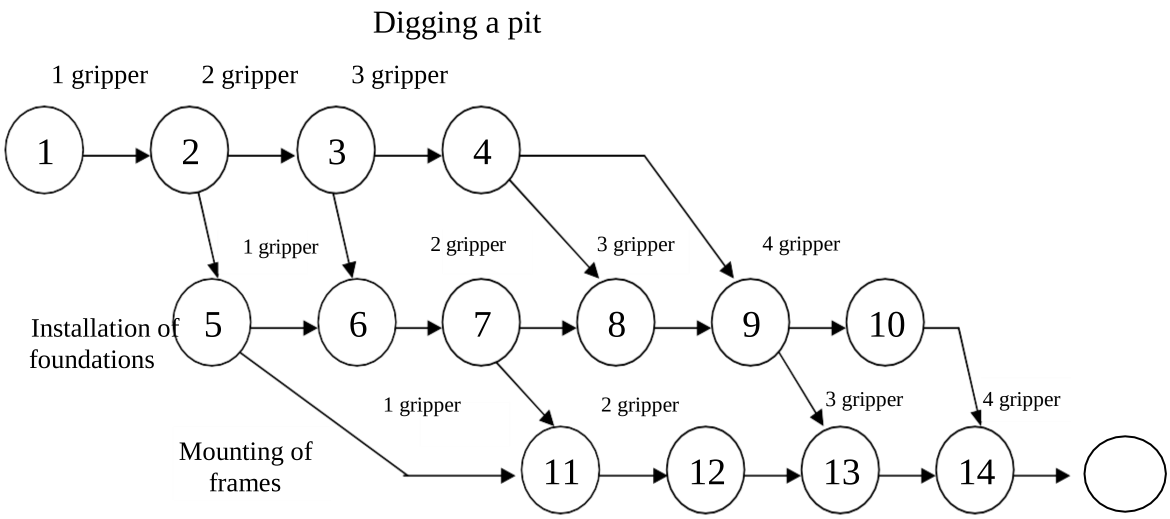


Figure 6.5 – An example of a flow of homogeneous work

6.4.4 Comparison of network graphs of the "node-work" and "event nodes"

Node-event charts have a longer history, they appeared in the 50s. It was only in the late 60s that network charts of the "nodes-jobs" type appeared only in the late 60s. Nowadays, the network graphs of the "vertex-work" type are becoming more and more widely used for the following reasons:

1. The absence of events and dotted dependencies allows you to determine the relationship of work before building a network graph from the table of initial data table. Each activity is assigned a permanent number (code) that does not depend on changes and additions to the network schedule. The separate position of each activity allows you to enter special codes for all performers.

2. More convenient construction of the network schedule. All rectangles can be drawn on a sheet, and then organizational and technological dependencies are placed between them. Adding new activities and links, as well as deleting previously existing ones, is done without changing the network graph topology. This cannot be done for node-event network diagrams, since the activities are located between two events, which implies a different logic.

3. Writing application programs for node-work networks is the easiest thing to

do, so most modern application programs are applicable only for such network graphs.

4. Node-robot network graphs are adapted to management standards and are used in specialised planning and operational management software packages.

6.4.5 Temporal parameters of the network schedule

Each activity of the network schedule has a time estimate - duration. The duration (t) of a task is measured in units of time: hours, days, weeks, etc.

Any continuous sequence of activities in the network schedule is called a path. The path from the initial to the final activity (event) is the complete path of the network schedule. If you know the duration of each activity, you can determine the duration of the path. The duration of any path is equal to the sum of the durations of its activities. The complete path with the longest duration is called the critical path.

The critical path duration (CPD) determines the total construction duration. Therefore, to reduce the construction duration, it is necessary to reduce the duration of critical activities, i.e. activities that are on the critical path. One of the main tasks of construction managers is to closely monitor compliance with the established time limits for these particular works, finding ways to reduce them and taking prompt action to prevent their disruption.

To determine the duration of the critical path and the timing of each work, the following time parameters of the network model are determined:

– early start of work – t^{es};

– early finish of work – t^{ef};

– late start of work – t^{ls};

– late finish of work – t^{lf};

– total time float – R;

– free time float – r.

Early start is the earliest time when the work starts. The early start of the outgoing activities of the network schedule is zero. The early start of any activity is equal to the maximum early end of the previous activities:

The early finish of a job is the earliest time at which the job ends. It is equal to the sum of the early start and the duration of the activity.

Late finish is the latest time at which the activity is completed and the critical path duration does not change. The late finish of the final work is equal to the duration of the critical path. Late finish of any activity is equal to the minimum late start of subsequent activities.

Late start is the latest time at which the critical path duration does not change. It is equal to the difference between the late finish of the activity and its duration. For activities on the critical path, the early and late start and finish times are equal to each other, so they have no time floats. Activities that are not on the critical path have time floats. The total float is the maximum time by which you can extend the duration of the activity or postpone its start without increasing the duration of the critical path. It is equal to the difference between the late and early start or finish time of the activity.

Free float is the time by which you can extend the duration of the activity or postpone its start without changing the early start of subsequent activities. It is equal to the difference between the early start of the subsequent work and the early finish of this work.

6.5 Calculating the node-to-date network schedule

To calculate the node-activity network graph, the rectangle representing the activity is divided into seven parts (Fig. 6.6). In the upper three parts of the rectangle, the early start, duration, and early finish of the activity are recorded, and in the lower three parts, the late start, time floats, and late finish are recorded. The central part contains the code (number) and the name of the work.

The calculation of the network schedule begins with the determination of the early start. The early start and finish times are calculated sequentially from the initial to the final activity. The early start of the initial activity is 0, the early finish is the sum of the early start and the duration of the activity:

$$t^{ef} = t^{es} + t .$$

For example, for work (1): $t_1^{ef} = t^{es} + t = 0 + 2 = 2.$

t^{es}	t	t^{ef}
activity code and title		
t^{ls}	***R/r***	t^{lf}

Figure 6.6 – Working in a node-activity graph

The early start of a subsequent activity is equal to the early finish of the previous activity. If a given work is immediately preceded by several works, then its early start will be equal to the maximum of the early finishes of the previous works:

$$t^{es} = \max\{ t^{ef} \}.$$

For example, for work (5): $t^{es} = \max\{t^{ef}; t^{ef}\} = \max\{7;5\} = 7$.

Thus, the early dates of all the activities in the network schedule are determined and entered in the upper right and left parts.

The early completion of the final activity determines the duration of the critical path.

Late finishes are calculated in the reverse order from the final to the initial work. Late completion of the final work is equal to its early completion, i.e. the duration of the critical path: $t^{ef}_{10} = 20$.

Late start is defined as the difference between late finish and duration:

For example, for work (10): $t^{ef}_{10} = 20 - 1 = 19$.

The late start of a subsequent job becomes the late finish of the previous job. If a given job is directly followed by several jobs, then its late end will be equal to the minimum of the late starts of the subsequent jobs:

$$t^{lf} = \min\{t^{ls}\}.$$

For example, for work (5): $t^{lf}_5 = \min\{t^{ls}_7; t^{ls}_8; t^{ls}_9\} = \min\{17; 15; 12\}=12$.

Similarly, the late finishes for all activities of the network schedule are determined and recorded in the lower left and right parts.

The total float, equal to the difference between the late and early finishes, is entered in the numerator in the middle of the bottom part:

$$R = t^{ls} - t^{es} = t^{lf} - t^{ef}$$

For example, for work (3): $R_3 = t^{ls} - t^{es} = 4 - 2 = 2 = t^{lf} - t^{ef} = 7 - 5 = 2.$

The free float, equal to the difference between the minimum early start of the subsequent work and the early finish of this work, is recorded in the denominator of the middle of the bottom part of the:

$$r = \min\{\{t^{es}\} - t^{ef}$$

For example, for work (3): $r_3 = \min\{\{t^{es};\ t^{es}\} = \min\{7; 5\} - 5 = 5 - 5 = 0.$

The free reserve is always less than or equal to the total float of work. An example of calculating a node-activity network graph is shown in Fig. 6.7.

The sequence of activities with zero time reserves is the critical path of the network graph. In this example, activities 1, 2, 5, 9, 10 are on the critical path, the duration of which is Tc = 20.

6.6 Calculating a node-event network graph

In Fig. 6.8 shows a node-event network graph that includes the same activities as the node-activities graph (Fig. 6.7). There are several algorithms for calculating such a graph. The most common of them are the algorithm for calculating a network graph in tabular form and directly on the graph.

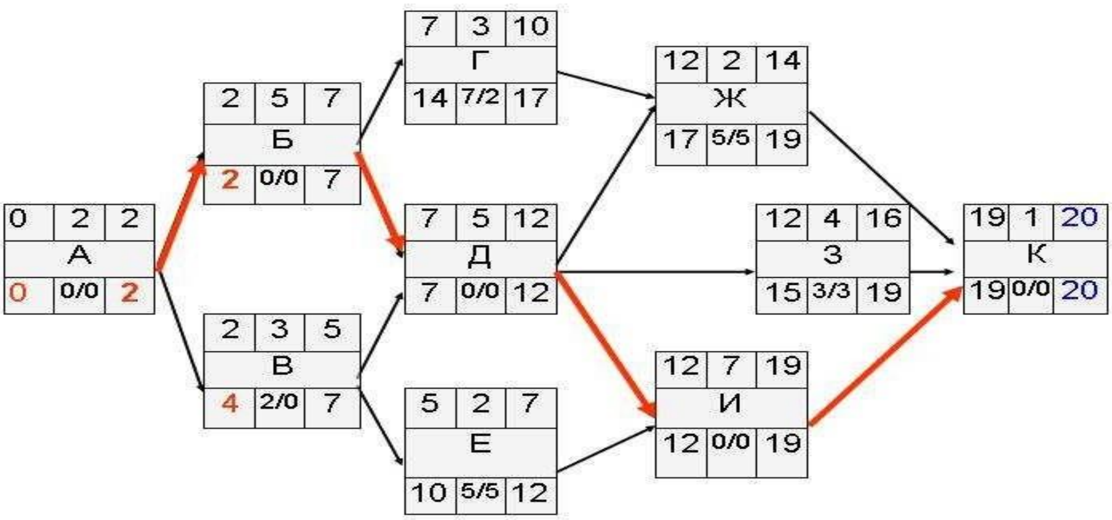


Figure 6.7 – An example of calculating a node- activity network graph

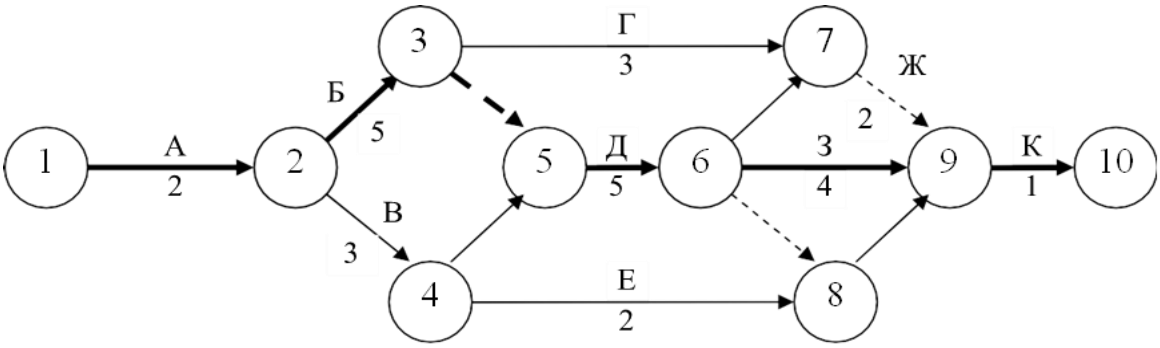


Figure 6.8 – An example of calculating a node-event network graph

Algorithm for calculating a network graph in tabular form. To calculate a network graph in a table, it is necessary that the events are numbered as follows: the number of the initial event of each activity must be less than the number of its final event. The ascending event is assigned the first number, and all subsequent events are assigned numbers in ascending order from the initial to the final event. After numbering, each activity receives its own code corresponding to the numbers of its start and end events.

The initial data from the schedule for the calculation are entered in columns 1, 2 and 3 of the table (see Table 6.2). All three columns are filled in simultaneously.

Table 6.2 – Calculation of a network graph in a table

Starting event numbers of previous works	Work code (ij)	Duration of work	Early start $t_{i,j}^{es}$	Early finish $t_{i,j}^{ef}$	Late start $t_{i,j}^{ls}$	Late finish $t_{i,j}^{lf}$	Total float of working time $R_{i,j}$	Free float of working time $r_{i,j}$
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
-	(1,2)	2	0	2	0	2	0	0
1	(2,3)	5	2	7	2	7	0	0
1	(2,4)	3	2	5	4	7	2	0
2	(3,5)	0	7	7	7	7	0	0
2	(3,7)	3	7	10	14	17	7	2
2	(4,5)	0	5	5	7	7	2	2
2	(4,8)	2	5	7	10	12	5	5
3,4	(5,6)	5	7	12	7	12	0	0
5	(6,7)	0	12	12	17	17	5	0
5	(6,8)	0	12	12	12	12	0	0
5	(6,9)	4	12	16	15	19	3	3
3,6	(7,9)	2	12	14	17	19	5	5
4,6	(8,9)	7	12	19	12	19	0	0
6,7,8	(9,10)	1	19	20	19	20	0	0

In column 1, enter the numbers of the initial events of the previous works. For example, for job (7,9) (Fig. 6.8), the preceding jobs are job (3,7) and dependency (6,7), so in column 1, enter the numbers of the initial events of these jobs 3 and 6.

In gr. 2, the codes of activities and dependencies are entered in ascending order of the initial event numbers, i.e., first the activities that result from event 1, then from event 2, etc.

In gr. 3, the duration of the work is indicated.

Early start and finish dates are calculated from the table from top to bottom. The early start of the activities starting from the first event is zero. The early finish is the sum of the early start and the duration of the work:

$$t_{i,j}^{ef} = t_{i,j}^{es} + t_{i,j}.$$

For example, for work (1,2):

$$t_{1,2}^{ef} = t_{1,2}^{es} + t_{1,2} = 0 + 2 = 2.$$

The early start of the subsequent work is equal to the highest of the early finishes of the previous work:

$$t_{i,j}^{es} = max\{t^{ef}\}.$$

For example, for work (5, 6):

$$t_{5,6}^{es} = max\{t^{ef}; t^{ef}\} = \max\ \{7;5\} = 7.$$

In the same way, determine the early start and finish of all works and enter them in columns 4 and 5 of Table 6.2.

The maximum early finish of the activities included in the final event determines the duration of the critical path. In this example, $t^{ef}_{9.10} = 20$.

Late start and finish dates are recorded in columns 6 and 7 of Table 6.2.

The calculation is carried out in the table from the bottom up.

For the activities included in the final event, the late finish is equal to the duration of the critical path: $t^{lf} = 20$.

The late start of any activity is determined by the difference between its late finish and duration:

$$t_{i,j}^{ls} = t_{i,j}^{lf} - t_{i,j}.$$

For example, for work (9, 10):

$$t_{9,10}^{ls} = t_{9,10}^{lf} - t_{9,10} = 20 - 1 = 19.$$

The late finish of any activity is equal to the least late start of subsequent work:

$$t_{i,j}^{ls} = \min \{t^{ls}\}.$$

For example, for work (2, 4): $t_{2,4}^{ls} = \min\{t^{ls}; t^{ls}\} = \min\{7;10\} = 7$.

Late finishes for all activities in the network schedule are determined in the same way.

The total float is equal to the difference between late and early finishes:

$$R = t^{lf} - t^{ef} = t^{ls} - t^{es}.$$

For example, for work (2, 4): $R_{2,4} = 7 - 5 = 4 - 2 = 2$.

The total float is entered in column 8 of Table 6.2.

For critical path activities, the total float is zero. We define critical activities, that is, activities that lie on the critical path, as (1, 2); (2, 3); (3, 5); (5, 6); (6, 8); (8, 9); (9, 10). The critical path of this network graph (Fig. 3.8) will be (1, 2, 3, 5, 6, 8, 9, 10).

The free float is entered in column 9 of Table 6.2, it is determined by the difference between the early start of the subsequent work and the early finish of this work:

$$r_{i,j} = t_{j,k}^{es} - t_{i,j}^{ef}.$$

For example, for work (3, 7):

$$r_{3,7} = t_{7,9}^{es} - t_{3,7}^{ef} = 12 - 10 = 2.$$

The free operating float is always less than or equal to its total float:

$$r_{i,j} \leq R_{i,j}.$$

According to the above algorithm, all calculations are carried out in Table 6.2 using the following formulas.

6.7 Algorithm for calculating directly on a network graph

To calculate directly on the network graph, each event is divided into four sectors (Fig. 6.9).

First, determine the early start of the network graph. The calculation is carried out from left to right from the initial to the final event. In the left sector of the upstream event (1) (Fig. 4.10) write "0" because the early start of activities resulting from this event is zero. There are no previous activities near the initial activities of the network schedule, so "0" is also written in the lower sector.

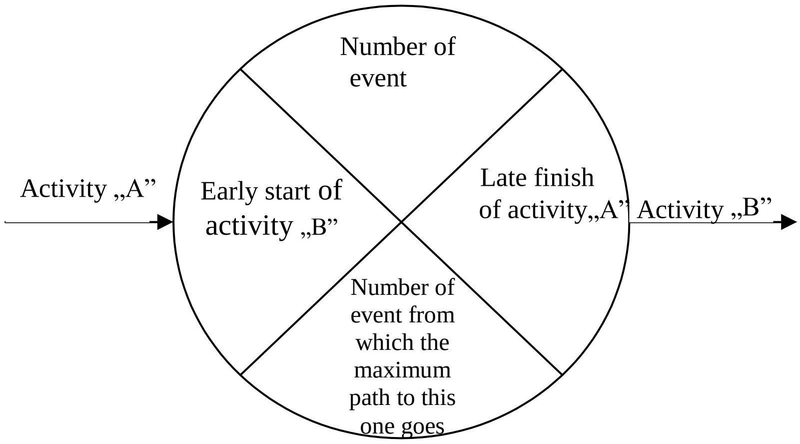


Figure 6.9 - Contents of the event sectors

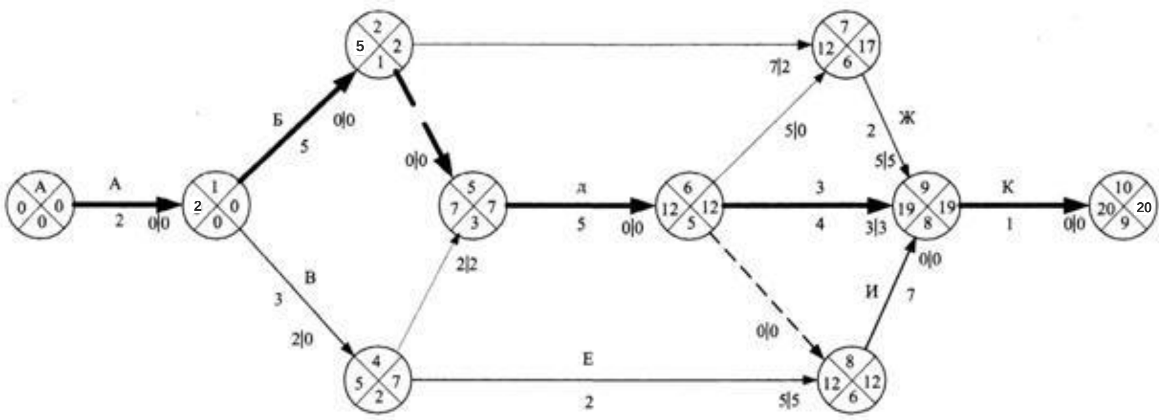


Figure 6.10 - Example of calculation on a network graph of "nodes-events"

The early start of the subsequent activity is equal to the maximum early finish of the previous activity, i.e. the maximum sum of the early start and the duration of the previous activity:

$$t_{j,k}^{es} = \max\{t_{i,j}^{es} + t_{i,j}\}.$$

For example, for work (7, 9):

$$t_{7,9}^{es} = \max\{(t^{es} + t_{3,7}); (t^{es} + t_{6,7})\} = \max\{(7+3); (12+0)\} = 12.$$

In the left sector of the event (7), write 12 - the early start of work (7,9), in the lower sector write 6 - the number of the event from which the maximum path to this one goes. The early starts of all activities are determined in the same way. Activities that start from the same event have the same early start. In the left sector of the final event (10), enter the maximum value of the sum of the early starts and the duration of the final activities – this will be the duration of the critical path.

For this example: $T_{cp} = t^{es} – t^{ef} = 19 + 1 = 20$. We put 20 in the left sector of event (10) and event (9) in the lower sector.

Next, we define the critical activities. The critical path is completed by event (10), in the lower sector of which we write 9. Therefore, event (9) is also on the critical path, in the lower sector of which there is an 8, that is, the critical path passes through event (8), in the lower sector of which there is a 6, which means that event (6) is on the critical path, and so on to the upstream event. In this example, the critical path includes events (1, 2, 3, 5, 6, 8, 9, 10), critical activities: (1,2); (2,3); (3,5); (5,6); (6,8); (8,9); (9,10). Late completion is determined from right to left from the final to the upstream event.

The late completion of the final work is equal to the duration of the critical path, so 20 is placed in the right-hand sector of event (10).

The late finish of the preceding activities is equal to the minimum difference between the late finish and the duration of the subsequent activities:

$$t_{i,j}^{lf} = \min\{t_{j,k}^{lf} + t_{j,k}\}.$$

For example, for work (2, 4):

$$t_{2,4}^{lf} = \min\{(t_{4,5}^{lf} - t_{4,5}); (t_{4,8}^{lf} - t_{4,8})\} = \min\{(7-0); (12-2)\} = 7.$$

In the right-hand side of event (4), write 7. All activities included in one event have the same late finish time.

After calculating the early and late finishes, the time floats are determined.

The total time float of an activity is equal to the difference between the late finish and the sum of the early start and the duration of this activity:

$$R_{i,j} = t_{i,j}^{lf} - (t_{i,j}^{es} + t_{i,j}).$$

For example, for work (3, 7):

$$R_{3,7} = t_{3,7}^{lf} - \left(t_{3,7}^{es} + t_{3,7}\right) = 17 - (7 + 3) = 7.$$

The free float of working time is equal to the difference between the early start of the subsequent work and the sum of the early start and the duration of this work:

$$r_{i,j} = t_{j,k}^{lf} - (t_{i,j}^{es} + t_{i,j}).$$

For example, for work (3, 7):

$$r_{3,7} = t_{7,9}^{lf} - \left(t_{3,7}^{es} + t_{3,7}\right) = 12 - (7 + 3) = 2.$$

Floats of work time and dependencies are recorded on the graph under the arrow: total float on the left, free float on the right.

Questions for self-examination:

1. Name the organizational and technological models of construction production.
2. What is the purpose of network models and network graphs?
3. Give a classification of network models.
4. Name the elements of network graphs.

TOPIC 7 CONSTRUCTION SCHEDULING

Questions for theoretical preparation

7.1 The essence of scheduling, its role in construction.

7.2 Types of calendar plans (schedules).

7.3 Simplified forms of calendar planning.

7.4 Linear calendar schedules.

7.5 The main provisions of calendar planning.

7.6 Construction schedules for complexes of buildings and structures.

7.1 The essence of scheduling and its role in construction

Scheduling is an integral element of the organization of construction production at all its stages and levels. The normal course of construction is possible only when it is thought out in advance in what sequence the work will be carried out, how many workers, machines, mechanisms and other resources will be required for each work. Failure to do so leads to inconsistencies in the actions of contractors, interruptions in their work, delays and, of course, higher construction costs. To prevent such situations, a calendar plan is drawn up, which serves as a work schedule within the accepted construction duration. Obviously, the changing situation on the construction site may require significant adjustments to such a plan, but in any case, the construction manager should have a clear idea of what needs to be done in the coming days, weeks, and months.

The duration of construction is usually set according to standards depending on the size and complexity of the facilities under construction, for example, the area of hydro melioration systems, types and capacity of industrial enterprises, etc. In some cases, the construction duration may differ from the normative one (most often in terms of tighter deadlines) if required by production needs, special conditions, environmental programmes, etc.

For facilities being built in difficult environmental conditions, it is permissible to extend the construction period, but this must always be properly justified.

In construction practice, simplified planning methods are often used, when, for example, only a list of works with deadlines is drawn up without proper optimisation. However, such planning is only acceptable when solving small current tasks during construction. When planning larger projects for the entire construction period, careful work is required to select the most appropriate sequence of construction and installation works, their duration, the number of participants, and to take into account the many factors mentioned above. For these reasons, various forms of scheduling are used in construction, allowing for optimisation of the planned course of work, the possibility of manoeuvres, etc:

- - linear calendar schedules;
- - grid charts.

In addition, depending on the breadth of the tasks to be solved and the required level of detail of solutions, there are different types of schedules that are used at different levels of planning.

When developing schedules for the Construction Management Project and the Works Execution Project, the best results are achieved when several variants of the schedule are drawn up and the most efficient one is selected.

7.2 Types of calendar plans (schedules)

There are four types of schedules, depending on the breadth of the tasks to be solved and the type of documentation they include. All types of schedules should be closely linked to each other. *Consolidated calendar plan* (schedule) in the construction management project (CMP) determines the order of construction of facilities, i.e. the start and end dates of each facility, the duration of the preparatory period and the entire construction. As a rule, a separate schedule is drawn up for the preparatory period. The existing regulations provide for the preparation of calendar plans in the project of work execution (PWE) in monetary form, i.e. in thousands of hryvnias, divided by quarters or years (for the preparatory period – by months).

For complex facilities, especially water management and hydrotechnical facilities, *summary schedules are additionally* drawn up based on physical volumes.

As we have already mentioned, when drawing up construction schedules for hydraulic and water management structures, it is necessary to carefully link the progress of construction work with the timing of water flow gaps in the river, the timing of channel closure and reservoir filling. All of these deadlines should be clearly reflected in the schedule. During the reconstruction of such facilities, minimal interruptions in the operation of the hydroelectric power station or hydraulic structure should be ensured.

At the stage of developing the consolidated schedule, the issues of dividing the construction into phases, start-up complexes, and technological units are resolved. The schedule is signed by the project's chief engineer and the customer (as the approving authority).

The object calendar schedule in the work execution project (PWE) determines the sequence and terms of execution of each type of work at a specific object from the beginning of its construction to commissioning. Usually, such a plan has a breakdown by months or days, depending on the size and complexity of the object. The object calendar plan (schedule) is developed by the compiler of the work execution project (PWE), that is, the general contractor or a specialized project organization engaged for this purpose.

When developing calendar plans for the reconstruction or technical re-equipment of an industrial enterprise, it is necessary to coordinate all deadlines with the enterprise.

Working calendar schedules are usually prepared by the production and technical department of a construction organization, and less often by line staff during the period of construction and installation works (CIW). Such schedules are developed for a week, a month, or several months. Weekly and daily schedules are most commonly used. Working calendar schedules are an element of operational planning that should be maintained continuously throughout the construction period.

The purpose of work schedules is, on the one hand, to detail the project schedule, and on the other hand, to respond in a timely manner to all kinds of changes in the construction site environment. *Work schedules* are the most common type of scheduling. As a rule, they are drawn up quickly and often have a simplified form, meaning that, as practice shows, they are not always properly optimised. Nevertheless, they take into account the actual situation on the construction site better than others, as they are drawn up by persons directly involved in the construction. This is especially true for weather conditions, the interaction of subcontractors, and the implementation of various rationalisation proposals, i.e. factors that are difficult to account for in advance.

Hourly (minute) schedules in flow charts and workflow charts are created by the developers of these charts. These schedules are usually carefully thought out and optimised, but they are only based on typical (most likely) working conditions. In specific situations, they may require significant adjustments. Depending on the stage of design, schedules are divided into the following types:

– a calendar plan or a comprehensive integrated grid schedule (CIGS) for the construction of a complex of buildings or structures as part of a construction management project (CMP);

– a schedule for the construction of individual facilities as part of a project for the execution of works (PEW); at the stage of working drawings;

– schedule of individual construction processes – technological maps at the stage of development of the project of works execution (PWE);

– hourly variable schedules are also developed, which are used in the work of prefabricated housing plants (PHPs) for the installation of structures from vehicles ("off the wheels").

All of the above schedules should be interconnected if they are developed for the same facility or facility complexes.

7.3 Simplified forms of calendar planning

In short-term planning, as we have already noted, construction practice often uses a simplified form of scheduling in the form of a list of works with deadlines for their completion. Such a form is not very visual and is not suitable for optimisation, but it is acceptable for solving current tasks for the next few days or weeks due to its simplicity and speed of preparation. This is usually the result of an agreement on the timing of work between the contractors, which is recorded in the form of minutes of a technical meeting, an order of the general contractor or other current document.

The simplified form also includes planning construction in cash. In this case, some optimisation is possible, but it addresses such issues only in an extremely generalised way, as it relates primarily to construction financing. A schedule in monetary terms is usually drawn up for particularly large volumes of work, when the planning element is an entire facility or complex of facilities. Such plans are typical, for example, for a construction organization project (CMP).

7.4 Linear calendar schedules

A linear calendar schedule (Gantt chart) is a table "works (objects) - time", in which the duration of works is depicted in the form of horizontal line segments. Such a schedule provides opportunities to optimise construction and maintenance activities according to a variety of criteria, including the uniformity of the use of labour, machinery, construction materials, etc. The advantage of line graphs is also their clarity and simplicity. The development of such a schedule includes the following steps:

1) compiling a list of works for which the schedule is being made;

2) determining their production methods and volumes;

3) determining the labour intensity of each type of work by calculations based on existing time standards, aggregated standards or local experience;

4) preparation of the initial version of the schedule, i.e. preliminary determination of the duration and calendar deadlines for each activity and displaying these deadlines on the schedule;

5) optimisation of the schedule, i.e. ensuring uniform resource requirements (primarily labour), ensuring timely completion of construction, etc., setting the final schedule and number of contractors.

The results of each stage of the development of the schedule should be carefully checked, as mistakes are usually not compensated for at subsequent stages. For example, if at the first stage the scope of any work is estimated incorrectly, its duration and deadlines will be incorrect, and the optimisation will be fictitious.

When determining the labour intensity of work, special attention should be paid to the reality of the calculations made, taking into account the specific working conditions. The latter may differ significantly from those set out in the standards, so the schedule maker must be well acquainted with the actual construction conditions.

The main disadvantage of linear schedules is the difficulty of adjusting them in case of violation of the original terms of work or changes in the conditions of their implementation. These disadvantages are eliminated by another form of scheduling - grid schedules.

7.5 Main provisions of calendar planning

Based on the terminology of project management, which refers to a set of actions, performers and means for the successful and high-quality completion of construction of facilities or their complexes, a project management strategy should be developed at the project preparation stage. The content of the management strategy is shown in the diagram in Fig. 7.1.

The strategy is adjusted and refined during the design process. Based on the strategy, detailed project work plans are formed.

In parallel to the main works, operational management is carried out in accordance with the previously developed plans, taking into account difficult situations in the course of work. Scheduling occupies a special place in the complex of construction planning and management tasks. This is primarily due to the role played by the specifics of construction production in balancing the time and coordinating the activities of numerous participants in the production process.

A schedule is a design and technological document that determines the sequence, intensity and duration of work, their interconnections, as well as the need (with a time distribution) for material, technical, labour, financial and other resources used in construction.

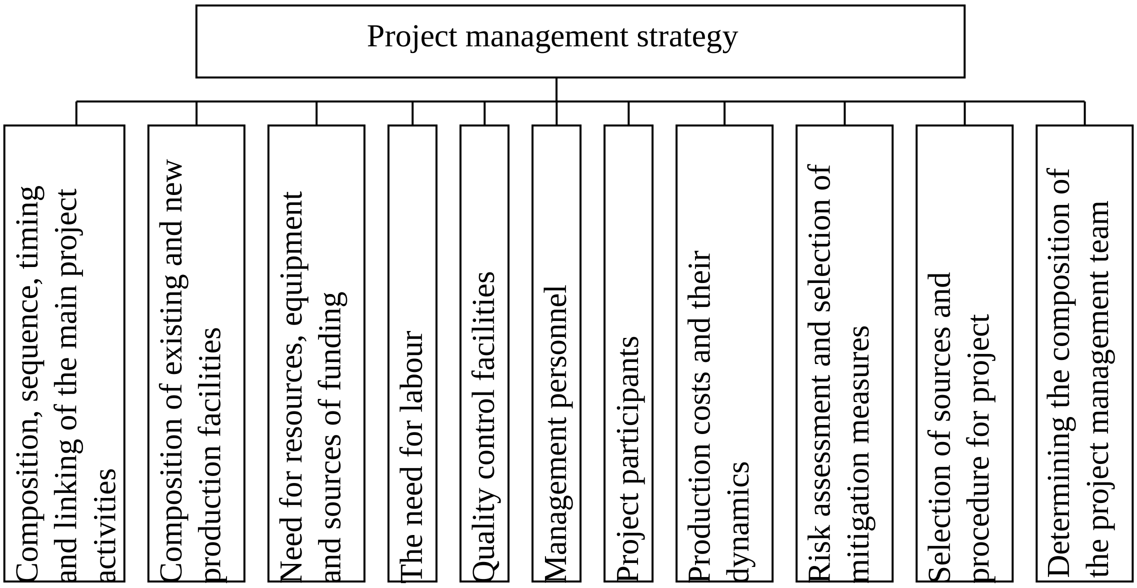


Figure 7.1 - Requirements for a project management strategy

Rational construction scheduling is based on a normalised technology for the construction of buildings and structures. It is usually reflected in the technological models of facility construction.

The main task of scheduling is to draw up such work schedules that would satisfy all the constraints reflected in the technological models of facility construction, interrelationships, terms of intensity of work, and the rational use of resources.

If a quality criterion for the schedule is formulated in advance (for example, the minimum duration of construction or the maximum uniformity of the use of teams of workers and construction machines), the schedule that is optimal according to this criterion is considered to be the best.

Solving scheduling tasks based on such technological models that take into account the need for specific resources, at the same time allows for the most efficient allocation of these resources at individual sites and across the construction organization as a whole. However, on large construction projects, the use of mathematical methods and computer technology is usually required to obtain the best, i.e. optimal or at least close to rational, result. In simpler cases, it is often possible to obtain a good enough solution manually.

The organization and planning of construction involve the coordination of work in time and space, i.e. the development of a model for the execution of a set of works agreed in time and space in order to achieve high technical and economic performance of construction production.

7.6 Construction schedules for complexes of buildings and structures

Construction objects consisting of a complex of buildings and structures include residential areas (residential neighbourhoods, urban development complexes, groups of residential buildings), social purpose complexes (hospitals, sanatoriums, sports complexes, shopping malls, etc.), as well as industrial enterprises.

The duration of construction is regulated by the standards for the duration of construction and the construction of enterprises, buildings and structures (currently in force in Ukraine, DSTU B A.3.1-22:2013).

The provision of financial resources, design and estimate documentation, material, technical and labour resources for construction should be carried out in the amount and within the timeframe that ensures compliance with the applicable standards. In addition to the total duration of construction of new and expanding enterprises, the standards establish the duration of construction of individual phases of start-up complexes, workshops and production facilities (Table 7.2).

The development of a large residential neighbourhood should be carried out in the form of complete urban development complexes.

Table 7.2 – Schedule of the main period of construction of the first stage of an agricultural product processing plant

Name	Volume of construction and installation works works, UAH million.		Distribution of the scope of work		
	In total	including equipment installation	**2019**	**2020**	**2021**
1	2	3	4	7	6
Preparatory period	3777,2	-	3777,2	-	
The main production facilities purpose					
The first stage: production building	9880	864,0	480	1680,0	7720
Lime kilns and roasting furnaces	788	62	-		788
Auxiliary and production facilities: warehouse building	5804	263	240	4760	804
factory office	309	-	-	309	
Engineering communications and roads: industrial water supply	2693	-	600	1872	221
fire protection and domestic water supply etc.	1572	140	1200	372	

An urban development complex is a part of a neighbourhood consisting of a group of residential buildings, institutions and enterprises related to servicing the population and the territory of the complex, provided with the necessary types of engineering equipment and landscaping. By the time residential buildings are commissioned, the construction of institutions and enterprises related to public services must be completed and all engineering equipment, landscaping and landscaping works must be completed in accordance with the approved development project for the microdistrict.

For each urban development complex, the number and types of residential buildings, their total area, as well as institutions and public service enterprises that must be completed by the time the residential buildings are put into operation, are determined.

Urban development complexes are formed as part of a neighbourhood with due regard to organizational and technological requirements: ensuring the necessary frontline of work for the deployment of a complex long-term flow, the possibility of autonomous functioning of the engineering networks of each complex independently of others, ensuring the necessary frontline of work for contractors involved in construction.

The development of residential neighbourhoods in urban planning complexes creates opportunities for organising construction using a comprehensive streaming method, ensures a certain architectural and planning completeness in the early years of construction, systematic development of the territory and high complexity of development, and contributes to more efficient investment.

The order of development of a neighbourhood is determined by the order of development of urban development complexes. When determining the order of development of a microdistrict, the following shall be taken into account:

– the nature of the relief of the construction area. Development should start from the plots that are subject to planning in the first place due to the conditions of drainage and distribution of earth masses;

– places of connection of neighbourhood utilities to the main ones. It is advisable to design the beginning of development from the side of the main supply networks and roads;

– the scope of work on preparing the territory for construction (relocation of utilities, alluviation, peat extraction, drainage, demolition); the number of residents occupying the buildings to be demolished, the order and timing of vacating non-residential buildings to be demolished and transferred to other areas. Development starts mainly with plots that have a minimum amount of site preparation;

Provision of amenities for residents of the buildings put into operation during the construction of the neighbourhood, provision of utilities to the area under construction and location of communal facilities, kindergartens and schools in the neighbourhood. Development is carried out in such a way that the inconvenience of residents during the construction period is minimised;

– priority of some plots is possible;

– costs for engineering equipment of the plots.

The economic justification of the order of development is carried out by calculating and comparing the volume of work in progress on the engineering equipment of the territory under different options for the sequence of construction, the different length of utilities and roads in each stage, including the main supply networks, causes different costs for their installation. The rational sequence of development is the one in which the cost of engineering networks that ensure the commissioning of residential buildings in each stage is the lowest. The order of development shall be determined in the following sequence:

– separately for each plot (urban development complex), according to the consolidated plan of engineering networks, the routes of engineering networks and roads that need to be laid to ensure the commissioning of houses are identified, assuming that each of the plots will be built first and there are no other options for development;

– for each plot (urban development complex), the scope and cost of engineering equipment of the territory is determined;

– as the first stage, the site characterised by the minimum cost of engineering equipment of the territory per 1 m2 of living space is accepted;

after selecting the first stage of construction, similar calculations are used to determine the sequence of construction of other plots, taking into account that the engineering networks are laid to the first plot.

Industrial enterprises that are to be built over several years are constructed in start-up complexes and phases to ensure that their production capacities are commissioned as quickly as possible.

A start-up complex is a closed production cycle that manufactures a certain type of product in the form of parts, semi-finished products and products used in subsequent production cycles.

The construction of industrial enterprises with start-up complexes is carried out when factory production consists of a number of closed cycles.

For example, large ferrous metallurgy industrial enterprises are characterised by a large number of buildings and structures that carry out a full metallurgical cycle consisting of several technological stages. These include the production of raw materials for blast furnace shops, blast furnace production, steel production, and finished rolled products. Start-up complexes for the construction of ferrous metallurgy facilities are divided into ore dressing and pelletising plants; sinter plants; coke oven batteries; blast furnace shops; open-hearth, oxygen-converter and electric arc furnaces; rolling and pipe rolling shops. Each complex has a specific technology represented by a different set of facilities.

Commissioning dates and the composition of start-up complexes should be linked to each other.

A construction phase is a set of facilities or their parts that ensure the production of finished products envisaged by the project for a given enterprise. A construction phase may consist of several start-up complexes.

Scheduling is based on the following principles:

– the duration of construction of industrial enterprises should not exceed the normative duration in accordance with DSTU B A.3.1-22:2013, and the duration of residential buildings should not exceed the prescriptive (planned) duration; cost, labour, material and energy costs for construction should be minimal;

– permanent facilities that can be used for the needs of builders should be built during the preparatory period;

– decisions on the range and volume of temporary buildings and structures, including mobile (inventory) buildings, which are erected during the preparatory period, should create conditions for highly productive labour of workers on the construction site;

– decisions on laying temporary water, heat and power supply networks and lighting of the construction site should facilitate the efficient use of construction machines and small-scale mechanisation;

– works that cannot be carried out or that cause significant cost increases in winter should be planned for the warm season;

– the construction of buildings, structures and their parts should be carried out by industrial methods based on the widespread use of prefabricated structures, products, materials and equipment, as well as sets of blocks of high factory readiness;

– construction, installation and special construction works should be designed using streaming methods in compliance with the technological sequence and technically sound combination of these works.

When developing the calendar plans for the development of a microdistrict by urban planning complexes, the following principles and requirements shall be additionally observed:

– works related to the development of the site and preparation of production facilities that apply to the entire microdistrict should be completed before the start of construction and installation works on the priority complex (laying of existing main engineering networks and utility facilities, lowering of the groundwater level, vertical planning of the territory, etc;)

– organizational solutions for on-site engineering preparation should provide a rational technological scheme of work combination, which provides for the completion of vertical planning before the start of all other works on the site, the implementation of part of the works on laying roads and underground networks before the start of construction of buildings, the completion of all works on underground networks and the main volume of works on roads and landscaping before the start of construction of the above-ground parts of buildings, the completion of all works on roads, landscaping and gardening (if the latter does not contradict the season)

– it is necessary to ensure compliance with the normative duration of construction of facilities, as well as completion of construction and commissioning of all facilities and works on engineering equipment, landscaping and gardening of the complex, as a rule, within one year;

– in order to reduce the time gap between the commissioning of the first and the last objects of the urban development complex, the objects within the complex should be constructed in parallel streams depending on the established deadlines for the completion of the next complex and the entire neighbourhood.

The initial data for the development of the complex construction schedule are:

– planning and design solutions of the complex project and estimate documentation containing data on the volume of work on the objects (in monetary terms), the general organizational and technological scheme of construction of objects, on the basis of which the complex flow is formed;

– construction duration standards, or specified terms of commissioning of facilities, as well as design standards for determining the need for resources and temporary facilities;

– data on construction conditions based on the results of engineering and economic surveys at the site;

– information on the possibility of providing construction with all types of resources (labour, machinery and material, taking into account the capacities of existing construction organizations and their facilities), as well as water and energy resources.

To organise timely preparation of the stream construction, to ensure advanced engineering preparation, normal technological conditions for the construction of the main buildings, commissioning of the finished facilities of the neighbourhood by start-up complexes, and the correct sequence of construction, the total time allocated for construction is divided into two periods - preparatory and main.

The following works are performed during the preparatory period:

– engineering preparation of the construction area with site development, including geodetic surveying, drainage, demolition of buildings, elimination or relocation of existing utilities, cutting or replanting of greenery, cutting and storage of plant soil, vertical planning, etc;

– construction of access roads to the construction site and construction of construction facilities, which include auxiliary buildings on the construction site, administrative and sanitary facilities for contractors (offices of contractors and foremen, control room, sanitary facilities, catering and recreation facilities), temporary warehouses for construction materials, prefabricated structures and parts, permanent structures used for temporary construction needs, temporary driveways;

– supply of main lines of engineering networks and laying of a part of intra-quarter underground communications and roads for the purpose of using them for construction needs, minimising the costs of installing temporary networks and roads and creating the necessary advance in these works in relation to the construction of the main buildings.

At the same time, intra-quarter engineering structures (transformer and heating stations, etc.) should be constructed.

Questions for self-examination:

1. What is the main objective of calendar planning?
2. Types of calendar plans.
3. Features of the development of calendar plans for the construction of residential complexes.
4. Specifics of the development of CSCP for the construction of industrial enterprises.
5. Reflection of new methods of construction organization in integrated calendar plans.

TOPIC 8 ORGANIZATION OF MATERIAL AND TECHNICAL SUPPORT FOR CONSTRUCTION

Questions for theoretical preparation

8.1 Organization of material and technical support

8.2 Organization of production and technological equipment

8.3 Organization and operation of the construction machinery fleet

8.1 Organization of material and technical support

Construction, which is one of the most material-intensive sectors of the economy, requires the use of various building materials, the range of which is constantly changing as it moves from one facility to another or from one stage to another. This complicates the supply of complete sets of products and structures to construction sites. It should be borne in mind that the material and technical resources supplied to construction sites are usually the result of the joint work of many companies that extract raw materials, produce materials, semi-finished products and structures.

The procurement process is divided into two parts: the procurement of resources and services on a competitive basis and their delivery to the site. Procurement and supply are understood as a system of measures aimed at providing production with material resources, performing work or services, and transferring the results of intellectual labour related to specific projects.

Logistics has undergone the most significant changes compared to other areas of construction companies' production activities. This is due to the elimination of the pre-1991 procurement system, according to which all construction projects were assigned to supplier companies that supplied resources at fixed prices in accordance with the specifications developed as part of the design and estimate documentation. The customer's functions in this system were to control and settle accounts with suppliers and deliver products to the site.

The transition to the priority of market relations is associated with changes in both construction organizations and their external environment.

The situation in the construction materials commodity market can be characterised by the following features:

– the modern approach to logistics is to provide construction organizations with full independence in solving problems of supplying both material and technical resources and services, while the state retains the function of regulation through the system of taxes, antimonopoly legislation, and customs duties;

– the freedom of entrepreneurial activity is legally fixed;

– there is no problem of shortage of material resources;

– an important role is assigned to the wholesale trade system;

– formation of a competitive market environment through the development of small business, entry of foreign suppliers into the Ukrainian market, and the emergence of a large number of small intermediaries.

The process of logistics is aimed at timely delivery of the necessary products, structures, technological equipment and other materials to warehouses or directly to the work sites.

This involves a range of relevant activities to conduct market research, search for channels and forms of procurement, organise delivery, storage and preparation of resources for production.

Material and technical support of construction in the market

The system of material and technical support of construction in the market conditions is focused on a network of industrial and construction enterprises, transport and energy organizations, research, design, educational and other institutions, and households. It is aimed at providing the construction industry with the necessary material and technical resources.

Assessing the overall situation in the commodity market for construction materials, it can be stated that enterprises and organizations operate in conditions characterised by sufficient freedom of business activity, which is fixed by law: they have the necessary economic independence in relation to management and governmental structures, have access to almost all resources, are free to choose counterparties in trade, procurement and business operations, and independently (based on their interests) dispose of The existing production capacities and volumes of construction materials generally fully meet the demand in this market. The problem of shortage of material resources for the construction industry has become a thing of the past with the transition to a new economic system.

Construction material and technical resources are divided into production, non-production and natural resources.

The purpose of the material and technical support of construction organizations is to:

– timely provision of construction production with the necessary types of resources of the required quality and quantity;

– improving the use of resources: increasing labour productivity, capital productivity, ensuring the rhythm of construction processes, reducing the turnover of working capital, full use of secondary resources, increasing investment efficiency and other indicators;

– analysing the organizational and technical level of construction production and the quality of construction and installation works (services) of their own organization and competitors, which allows them to develop proposals to improve the competitiveness of their products - buildings and structures (services), etc.

To achieve the above goals, a construction organization must constantly perform the following work:

1. Conducting market research on suppliers of building materials, structures, products, semi-finished products, etc. (services). It is recommended that suppliers be selected based on the following requirements: suppliers have a licence and sufficient experience in this area, a high organizational and technical level of production, reliability and profitability of work, ensuring the competitiveness of the building materials produced, etc., their acceptable price, simplicity of the scheme and stability of their supplies;

2. Normalisation of the need for specific material and technical resources.

3. Development of organizational and technical measures to reduce the norms and standards of material and technical resources consumption.

4. Search for channels and forms of material and technical support for construction production.

5. Development of material balances.

6. Planning of material and technical support of construction production.

7. Organization of provision of construction materials, structures, products, semi-finished products and other materials for workplaces.

8. Accounting and control of the use of material and technical resources.

9. Organization of collection and processing of construction waste.

10. Analysis of the effectiveness of the use of material and technical resources.

11. Stimulation of work to improve the use of material and technical resources.

Depending on these functions, the relevant material and technical support services (MTS) of construction production are determined.

These include:

– the logistics service, which must ensure and regulate the timely supply of raw materials, semi-finished products, and component parts for the production process. In addition, the supply and sales bodies ensure the performance of services in the scope, nomenclature and within the timeframe established by business contracts;

– warehousing and storage of materials, fuel, raw materials and finished products provided by the warehouse facilities, which are the production and technical base of the supply and sales system

– production and technological service for completing finished products. It is particularly important, as the construction of buildings and structures requires the delivery of a set of prefabricated elements strictly in accordance with calendar schedules. Therefore, the production and technological kitting service ensures the selection of products and structures strictly in a certain quantity and range, within a given time frame according to daily and hourly schedules agreed with construction organizations;

– tool and equipment service. It should provide production with tools, fixtures, technological equipment, moulds of high quality at minimal production costs. The availability of these items determines the success of the introduction of advanced technology and the mechanisation of labour-intensive work;

– the service of repair and mechanical production, which should ensure the working condition of a large and complex fleet of equipment and machinery by repairing and modernising them. The precise work of this service largely determines the results of the construction organization;

– transport processes service, which ensures the movement within and outside the construction site of huge masses of cargo necessary for the normal functioning of the production process. Process transport, which links individual processes into a single production system, requires particularly precise and rhythmic operation.

8.2 Organization of production and technological equipment

8.2.1 Production and technological equipment of resources

To ensure timely provision of construction sites and facilities with all types of material resources, construction organizations (mainly large ones) create a specialised unit - the production and technological equipment department (PTE). The system of production and technological equipment provides for the unity of the complete manufacture of structures and products, supply and transportation of all material resources in accordance with the technological sequence of construction projects, which contributes to the rational use of resources. The main advantage of the production and technological package is that the planning, organization and operational management of material resources supply is strictly linked to the technology and schedule of construction projects, the pace of work of contractors and production structures. The main task of the procurement department is to provide facilities with structures, large units, equipment and materials in accordance with the construction and installation schedules. The experience of complete supply of material resources for construction projects demonstrates the effectiveness of this form of procurement. The introduction of production and technological equipment reduces construction time, reduces the cost of construction and installation works, and increases labour productivity. This is achieved by reducing the labour intensity of construction and demolition works by increasing the construction readiness of structures, materials and products, reducing resource losses during storage, transportation, and reducing stocks of materials in on-site warehouses. The UWTC acts as a centralised customer and buyer of all material resources from suppliers and a single supplier of these resources to all departments of the construction and installation organization implementing the projects.

8.2.2 Objectives and content of a unified system of technological preparation of production

Technological preparation of production (TPP) is a set of measures that ensure the technological readiness of production, i.e. the availability of complete sets of design and technological documentation and technological equipment necessary to produce a given volume of products with the established technical and economic indicators. This is one of the most important stages of the SONT system, which is quite significant in scope and complexity. For example, the labour intensity of technological preparation in relation to the total labour intensity of the technical design of a product in one-off production is 20-25%, in mass production – 50-55%, and in large-scale and mass production – 60-70%. This is due to the fact that if you move from one-off production to batch production and then to mass production, the degree of technological equipment increases, and therefore the amount of work on solid waste increases.

The company's T&E is carried out by the departments of the chief technologist, chief metallurgist, and technological bureaus of the main shops, which are subordinated to foundry, forging, mechanical and assembly shops. The material base for them includes tool and model shops, technological laboratories, and pilot production.

The main stages of the TPE are:

– development of technological processes;

– design of process tooling and non-standard equipment;

– manufacturing of technological equipment (tooling and non-standard equipment);

– verification and adjustment of the designed technology and manufactured technological equipment.

The first stage involves selecting rational methods of manufacturing parts and assemblies and developing new technological processes. The following activities are mainly performed in the design of technological processes:

– selection of the type of workpiece;

– development of inter-shop routes;

– determining the sequence and content of technological operations;

– identification, selection and ordering of technological equipment;

– establishing the procedure, methods and means of technical quality control;

– assignment and calculation of cutting modes;

– technical standardisation of production process operations;

– determination of professions and qualifications of performers;

– organization of production areas (production lines);

– preparation of working documentation for technological processes in accordance with uniform standards.

At the second stage, the TPE designs models, dies, fixtures, special tools and non-standard equipment, and develops a technological process for manufacturing tooling that should be sufficiently versatile, but at the same time progressive, advanced and ensuring high quality of manufactured parts.

At the third stage of the process, all tooling and non-standard equipment is manufactured. This is the most labour-intensive part of technological preparation (60-80% of labour and funds of the total volume of TIP). Therefore, as a rule, these works are carried out gradually, initially limiting themselves to the minimum amount of essential equipment, and then increasing the degree of equipment and mechanisation of the production process to the maximum economically justified limits. At this stage, the existing equipment is redesigned (if necessary), and new and non-standard equipment and tooling, as well as production lines and product processing and assembly areas are installed and tested.

At the fourth stage, the TEP verifies and adjusts the designed technology; finally tests parts and assemblies (blocks) for manufacturability: checks the suitability and rationality of the designed tooling and non-standard equipment, the ease of disassembly and assembly of the product; establishes the correct sequence of these activities; conducts timekeeping of machining and assembly operations and finalises all technological documentation.

Technological documentation for different types of production (single-unit, batch and mass production) differs in the depth of process development and the degree of detail. Initially, inter-shop route maps are developed for the technological processes of manufacturing parts and assembly units. The route maps indicate the sequence of billets, parts or assembly units through the shops and production areas of the enterprise. For the manufacture of parts and assembly of a product in one-off or small-scale production, it is sufficient to have design documentation, a route or route-operational description of the technological process, or a list of the full composition of technological operations without specifying transitions and technological modes. For batch and mass production, in addition to the route technology, a technological process with an operational description of moulding, machining and assembly is investigated. During this process, an operational flow chart is developed for single technological processes, and a typical (group) operation map is developed for typical (group) technological processes. They specify all the transitions for a particular operation and how to perform each one, technological modes, data on technological equipment, materials and labour costs. Typically, operation maps contain sketch drawings depicting parts or parts of parts with indications of the dimensions and processing required to perform a particular operation (the method of fixing parts on the machine, the location of tools, fixtures, etc.).

8.3 Organization and operation of the construction machinery fleet

One of the main areas of technical progress in construction is the integrated mechanisation of production processes. Integrated mechanisation is a method of fully mechanised implementation of certain technological processes in construction, which is carried out by one or more machines.

Complex mechanisation of construction processes is a more advanced form of mechanisation compared to partial mechanisation of individual operations. A number of indicators are used to assess the state of mechanisation of construction and installation works and the provision of construction and installation organizations with mechanisation equipment. The indicators of mechanisation of works, which characterise the degree of coverage of construction and installation works by mechanisation, are the level of mechanisation and the level of complex mechanisation of works.

The level of mechanisation of works is determined by the ratio of the volume of mechanised works, where the main operation is performed by mechanisms, to the total volume of works performed with the help of machines and manually:

$$E_c = \frac{N_{total}}{C} \quad (8.1)$$

The level of complex mechanisation is determined by the ratio of the volume of complex mechanised works to the volume of mechanised works:

$$k_{mech} = \frac{V_{mech}}{V} 100 \quad (8.2)$$

Indicators of availability of construction machinery:

The availability of construction machinery is determined by the ratio of the book value of mechanisation equipment to the total cost of construction and installation works performed by own forces:

$$k_{k.mech} = \frac{V_{k.mech}}{V_{mech}} 100 \quad (8.3)$$

The provision of labour with machinery is determined by the ratio of the balanced cost of construction machinery and equipment to the average number of workers employed in construction:

$$M_c = \frac{C_{mech}}{C_{total}} 100 \quad (8.4)$$

Energy availability indicators evaluate mechanisation in terms of energy and are characterised by the relationship between an increase in machine power consumption and labour productivity growth.

The energy availability of construction is determined by the total power of engines installed on construction machines per UAH 1 million of annual volume of in-house construction and demolition works:

$$M_{lab} = \frac{C_{mach}}{n_p} \quad (8.5)$$

The energy supply of labour is determined by the total power of engines installed on construction machinery per worker employed in construction:

$$E_{lab} = \frac{N_o}{n_p} \quad (8.6)$$

Improving the use of the construction machinery fleet can only be achieved by creating a system that is coordinated by a set of main and auxiliary machines, vehicles, and small mechanisation equipment that provide comprehensive automation of mass construction and installation works.

2. There are four main forms of construction machinery operation. They correspond to the nature of relations with construction organizations and the procedure for settlements with them.

1 form of operation of construction machines - construction machines are on the balance sheet of construction organizations. The maintenance and operation of machines is managed by the chief mechanic service. Machines are allocated to sites at the request of line workers. Depending on the number of hours worked and the planning and budget estimates, the accounting department allocates the cost of operating the machinery to the cost of construction of the relevant facility.

The advantages of this form of construction machinery operation are: prompt deployment of machinery to the site; strong communication links between machinery operators and the management apparatus; and the disadvantages: underutilisation of machinery; machinery downtime; powerful machinery used at low capacity.

2 form of operation of construction machinery - construction machinery is part of and on the balance sheet of specialised mechanisation units that are subordinate to construction organizations. Operational management of the distribution and use of construction machinery, as well as all payments for its operation, is carried out by the construction and installation organization. Construction departments maintain machines on a lease or contract basis.

Compared to the first form, this scheme is more rational, as it ensures the qualified maintenance of construction equipment and its better use in terms of productivity. Builders and machine operators are under the same management.

3 form of construction machinery operation - construction machinery and equipment are part of and on the balance sheet of independent mechanisation enterprises that are subordinated to territorial construction associations.

Concentration of construction machinery at specialised mechanisation enterprises creates the most favourable conditions for its maintenance and servicing, ensures maximum use of machines in accordance with their technical parameters, and also allows concentrating a significant number of machines if necessary.

4 form of construction machinery operation - leasing - construction machinery and equipment are on the balance sheet of leasing companies specialising in leasing (renting) equipment for short-term or long-term use on a contractual basis.

The advantages of this form of operating a construction machinery fleet for a construction company are as follows

- There is no need to maintain its own highly complex repair and maintenance facilities;

- the possibility of using equipment of different parameters and capacity;

- reduction in the cost of works requiring the use of expensive equipment, especially in short-term projects.

5 form of construction machinery operation - construction machinery is owned by a private entrepreneur.

The choice of a specific organizational form depends on the scope and structure of construction and installation works, the type and complexity of the facilities, the level of construction concentration, the number of construction machines and the structure of their fleet. The right choice of organizational form, taking into account the above factors and specific local conditions, can increase the efficiency of construction machinery use.

3. In many technological processes, small-scale mechanisation has no less impact on labour productivity growth than large machines. By improving the

equipment of construction workers with mechanisation tools and increasing the efficiency of their use, it is expected that labour productivity in construction will increase significantly.

The regulatory framework contains a list of technological operations performed with the use of mechanised tools and equipment that ensure the performance of work at a modern and advanced technological level with the minimum possible manual labour costs.

Currently, there are several organizational forms of small-scale mechanisation (SSM) operation. The first form is when small-scale mechanisation equipment is on the balance sheet of the construction department. This involves a complicated specialisation of maintenance personnel in certain types of machines. In addition, the construction department needs to have a wide range of machines and tools that cannot be used efficiently but require a large number of maintenance personnel.

The second form is that small-scale mechanisation is concentrated in small-scale mechanisation departments or sections that are part of the general contracting trust. In this case, the small-scale mechanisation section or department serves all the construction divisions of the trust. This form allows to increase the efficiency of small-scale mechanisation through the specialisation of personnel and a higher level of operation and repair.

In practice, the concentration of small machinery in a department or section (the second form) that is part of the trust is the most efficient. Small-scale mechanisation equipment is distributed through a system of tool and distribution points to construction organizations. The concentration of small-scale mechanisation equipment in a specialised department (service) allows for

– improve the use, repair and maintenance of equipment;

– increase efficiency in solving production issues;

– create a nomenclature of modern small machinery;

– to form a team of highly qualified specialists;

– to achieve a significant increase in the mechanical equipment of the construction company;

– reduce the amount of manual work and increase labour productivity.

4. The effectiveness of construction machines depends mainly on the correct organization of accounting for their work at the construction site.

One of the documents that reflects the use of a construction machine during a shift is the driver's shift report. The report indicates the actual amount of operating materials used during the shift, as well as the duration of the machine's stay in repair. The data from the shift reports are transferred to the machine's performance record card, which summarises the machine's performance on a monthly basis. At the end of the year, the total data is entered into the machine's passport to monitor the machine's use, technical condition and repairs.

Ensuring the smooth operation of construction machines and reducing operating costs depends on the correct organization of the maintenance and repair system.

In accordance with the adopted unified system of preventive maintenance and repair, all work to ensure the technical readiness of construction machines, reduce and eliminate failures, and prevent accelerated machine wear is divided into: monthly maintenance (MRO); periodic maintenance after a set number of hours of machine operation (MRO-1, MRO-2, MRO-3); seasonal maintenance (SM), performed during the transition to the autumn-winter and spring-summer seasons; current repairs; and overhauls.

Monthly maintenance involves providing the machine with fuel, lubricants and other materials, moving the machine from one site to another, and storing it.

Periodic maintenance is a set of measures to detect faults and prevent excessive wear and tear of machine parts. Construction machinery maintenance is carried out according to a planned preventive maintenance system at a certain time and to a certain extent for the relevant types and models of machinery.

Repair is a set of technical measures that eliminate malfunctions in a machine and restore its performance. During machine repair, parts, components, assemblies and devices that are unsuitable for further use are repaired or replaced with new ones.

The system of preventive maintenance includes current and overhaul repairs. During current repairs, construction machines are partially disassembled, malfunctions in components and assemblies are eliminated, and parts, assemblies and components requiring major repairs are replaced with new or previously repaired ones. During a major overhaul, the machine is completely disassembled and worn-out components and assemblies are replaced. Overhauls of complex construction machinery are carried out at specialised plants.

Accounting for the operation of a construction machinery fleet should reflect the performance of mechanised work by the main indicators of their use, and should also contain data and analysis of downtime and material consumption. The main indicators of the correct operation of the construction machinery fleet are the actual annual physical volumes of work determined by the reported data in comparison with the planned task.

The utilisation rate of the construction machinery fleet over time is determined by the ratio of the number of machine days actually worked to the calendar number of machine days in operation during the same period (T):

$$k_{mach} = \frac{T'_{act}}{T'_{plan}} \tag{8.7}$$

The machine time utilisation rate is determined by the ratio of actual machine operating hours during the year to the planned operating hours set for the year:

$$k_t = \frac{P_{act}}{P_{plan}} \tag{8.8}$$

Machine utilisation rate by productivity is determined by the ratio of actual machine productivity to planned rates during the same period:

$$k_{prod} = \frac{T_{act}}{T_{plan}} \tag{8.9}$$

The machine availability rate is determined by the ratio of the number of machine hours worked by the same type of machines during the reporting period ($T_{machine\ hours}$) to the product of the number of machine days these machines were in operation ($T_{machine\ days}$) and the average working day for a five-day working week (t_{week}):

$$k_{avail} = \frac{T_{mach\ hohrs}}{T_{mach\ days} \cdot t_{week}} \tag{8.10}$$

The machine utilisation rate by time during a shift is determined by the ratio of the number of hours of machine operation during a shift:

$$k_{time} = T_{act.shift}/t_{shift} \quad (8.11)$$

The assessment of the above indicators is carried out by comparing the reported data with the standard indicators of machine output, utilisation, etc.

Questions for self-examination:

1. What is the basis for organising the material and technical support of construction?
2. Describe the principle of the complex mechanisation method.
3. What determines the efficiency of construction machines.
4. Define the main forms of machine operation.

TOPIC 9 ORGANIZATION OF CONSTRUCTION QUALITY CONTROL

Questions for theoretical preparation

9.1 The concept of product quality.

9.2 A comprehensive system of quality management of construction and installation works.

9.1 The concept of product quality

According to the international standards ISO 9000-9004, "quality is a set of properties and characteristics of a product or service that ensures the satisfaction of specified or anticipated needs".

Product properties can be either positive or negative.

The quality of products is determined by a set of positive properties. At the same time, the set of properties includes only those that are essential for meeting certain needs.

For example, a residential building must create certain comfortable living conditions for both the family as a whole and each of its members. For this purpose, it must have such properties as convenient apartment layout; availability of engineering equipment (water supply, sewerage, heat supply, etc.); heat and sound insulation of walls, ceilings, windows, strength of load-bearing structures, waterproof and weatherproof roofs and structures, fences; beautiful interior and exterior decoration, etc.

The level of quality is not a constant value, it changes due to changes in the needs of society, achievements of scientific and technological progress, therefore, the level of product quality is understood as a relative characteristic based on the comparison of quality indicators of the assessed products with their baseline values.

Labour quality is the ability and willingness of the workforce and individual employees to perform all tasks in a high-quality, cost-effective manner and on time. To do this, the performer must:

a) know how to perform the task, i.e. be trained, have relevant technical documentation, etc;

b) be able to perform the task, i.e. have the appropriate qualifications and experience

c) to be able to complete the task within the planned timeframe.

To reflect the quantitative characteristics of quality, quality indicators are used, which are divided into groups:

– indicators of purpose, which characterise the main functions for which the product is intended, as well as the scope of its application. For example, the main purpose of a residential building is to create comfortable living conditions for families of different sizes, etc.

– reliability indicators, including durability, reliability, and maintainability;

– ergonomic indicators, which characterise the compliance of products with the anthropometric, hygienic, physiological and psychological properties of people working with them; for example, doors in an apartment should have a certain height and width, which are linked to the size of the human body;

– aesthetic indicators: information expressiveness, rationality of forms, integrity of composition, perfection of execution, "fit" into the environment, etc. Aesthetic indicators are especially important for construction products, which usually last for many years, and improving their aesthetic performance during their operation is associated with high additional costs;

– manufacturability indicators characterise the optimal distribution of labour, materials and energy costs in the preparation of production, manufacturing and operation of products. These indicators are best achieved in the construction of facilities from standardised structures based on successful standard designs;

- transportability indicators: the ability to transport by road, rail, water, air, full use of containers, wagons, car bodies, etc. Accounting for this group of quality indicators is of great importance when organising the production of building materials, products and structures;

– standardisation and unification indicators - the degree of use of standard and unified elements;

– patent and legal indicators that characterise the degree of product novelty and the registration of this novelty by patents, licences, and copyright certificates;

– environmental indicators that characterise the degree of environmental impact of products, especially the degree of pollution of the atmosphere, water, soil, etc;

– safety indicators determined by the degree of protection of workers from harmful emissions, moving machine parts, etc;

– economic indicators: the estimated cost of the facility, the cost per 1 m2 of total and living space, operating costs, etc.

Due to the fact that any construction object and structural element of a building can have many quality indicators, in practice, a minimum but sufficient number of them is chosen to characterise the most essential properties of the product in accordance with its intended use.

The measurement of quality consists in expressing the values of quality indicators in the units of the chosen measurement scale. Indicators, in turn, are divided into single indicators, which characterise each single property of a product, and complex indicators, which characterise several properties at once. The calculation of a complex indicator is carried out taking into account all the single indicators provided for by the nomenclature. In this case, if an increase in a single indicator results in an increase in the complex indicator, then such a single indicator is desirable; if it decreases, it is undesirable. For example, for paint, the desirable indicator is its hiding power, while the undesirable indicator is the drying time; an increase in hiding power reduces the number of paint layers applied (and thus the labour intensity and time of work); an increase in drying time leads to an increase in the time required for construction and installation works.

Quality assessment is a comparison of quality indicators with baseline indicators, which may be:

a) indicators laid down in the project (working documentation);

b) quality indicators of the best domestic and foreign facilities;

c) quality indicators included in a national or foreign standard.

As a result of comparing the quality indicators of the assessed products with the baseline indicators, a conclusion is made about the level of product quality.

Quality requirements for construction products.

The successful operation of any enterprise in a market environment is possible only if its products meet the best domestic and international standards, because otherwise, in a competitive environment, significant economic losses, up to and including bankruptcy, are possible. Therefore, the main goal of the company is to organise the production of high-quality competitive products.

Along with organizational methods, economic methods are also used to improve product quality. A company pays discounts from wholesale prices for the production of outdated products and low-quality products, and incurs losses in income, and thus in wages and social benefits. In turn, products that meet or exceed the highest global standards are sold at higher prices.

Strict requirements must be imposed on the quality of construction products, as defects in the work of builders can (and do) lead not only to economic losses but also to the loss of life. This was particularly evident in the 1988 earthquake in Armenia, where thousands of people died due to design errors and poor quality of construction of residential buildings, schools and businesses; however, many buildings constructed in compliance with building codes and regulations did not collapse and the people inside them survived.

Quality requirements are formed by consumers (customers), developers, manufacturers and government agencies, with the priority in their formation belonging to the consumer.

Mandatory quality requirements for all production participants must ensure

– safety of human life and health;

– environmental protection and a high level of environmental safety;

– saturation of the domestic market with quality products and expansion of their exports;

– rational use of labour, material, energy and natural resources in the production and consumption of products, and technical compatibility.

Product quality requirements are set out in relevant regulatory and technical documents and contracts. With regard to construction, the quality requirements for construction and installation works are set out in the State Construction Standards. Quality requirements may also be contained in contractor agreements or capital construction contracts concluded between customers, general contractors and subcontractors. In any case, the quality of construction should be such that the constructed object complies with the design and estimate documentation and existing standards.

9.2 A comprehensive system of quality management of construction and installation works

A comprehensive construction quality management system has been developed to address the complex task of improving the quality of construction. This system is a set of measures, methods and tools aimed at establishing, ensuring and maintaining the required level of quality of construction and installation works.

Quality management includes the following functions:

1) Planning the quality of construction and installation works performed by teams, sites and the construction organization as a whole in accordance with the quality requirements for construction and installation works set out in the DBN and in projects. The company's standards are developed based on these requirements.

2) Preparation of construction production - ensuring the readiness of the construction organization to perform construction and installation works of a given scope and planned quality level.

3) Procurement departments provide construction with materials, products and structures on time, the quality of which must comply with industry standards and specifications. One of the tasks of procurement is also to maintain the level of quality during transportation and to preserve resources.

4) Quality control, information support and assessment of construction and installation works are carried out by the quality management service, chief technologist, construction laboratory, technology department, line engineers and foremen, as well as the geodetic group (chief geodesist).

5) Incoming quality control of project documentation is carried out. All quality-related departments and services are provided with regulatory and technical quality literature. The main regulatory document on the quality of construction and installation works is the State Construction Standards, which reflects the quality requirements for both general construction and specialised works.

6) Recruitment, placement and training of personnel is carried out by the HR department, training centre, heads of construction organizations, departments and services, and line engineering and technical personnel.

7) Material and moral incentives for employees to improve the quality of work shall be provided by the quality management service, the management of the construction company and line engineering and technical staff.

8) Legal quality assurance is carried out by the Senior Legal Counsel in conjunction with the Estimates and Contracts Department. Claims work is carried out by the legal adviser together with the accounting department. An important part of the integrated construction quality management system is the metrological support of

construction production, which means the establishment and application of scientific and organizational foundations, technical means, rules and regulations necessary to achieve unity, the required accuracy, correctness and reliability of measurements of construction product quality indicators and indicators of process stability.

The system of metrological support of a construction organization includes departments and services involved in the operation of control and measuring instruments and equipment (metrological service, construction laboratory, departments of chief technologist, chief mechanic, geodetic service, etc.)

The main task of the metrology service is to ensure the uniformity and reliability of measurements by

– compliance of regulatory and technical documentation requirements with the standards of the State System for Ensuring the Uniformity of Measurements and the State Standardisation System;

– introduction of measurement methods that meet modern requirements and ensure high quality of construction; constant monitoring of the condition and correct use of measuring instruments;

– improvement of the forms of metrological services provided to the departments of the construction organization.

One of the important elements that ensure the proper quality of construction is the geodetic service, which consists of a geodetic bureau (chief surveyor) and geodetic services of construction units. The works performed by the geodetic service are as follows:

a) acceptance of geodetic and topographical documentation for construction objects from the customer;

b) instrumental control over the correctness of construction and installation works in terms of compliance with the dimensions and geometric parameters of the project objects and the DBN;

c) preparation of geodetic executive documentation for submission to the working or state acceptance committee, etc.

The following measuring instruments should be available in the relevant departments:

- tools for controlling geometric parameters (levels, theodolites, laser devices, levels, squares, tape measures, control rails, etc;)

- tools for soil quality control: penetrometer for express method of determining soil density, pressiometer for determining deformation and strength characteristics of soils in boreholes; radioisotope device for determining density, etc;

- quality control equipment for concrete mix, concrete and reinforced concrete products: a standard cone for determining the mobility of concrete mix, cube moulds for making samples, a viscometer for determining the hardness of concrete mix, an ultrasonic device for determining the strength and uniformity of concrete and other building materials and structures, a moisture meter;

– quality control equipment for cement, cement mortar, gypsum, lime: devices for determining the density of cement, normal density of cement dough and setting time; cone with a tripod for determining the mobility of mortar mixture; device for determining the temperature and time of lime quenching, etc;

– quality control equipment for welding, anti-corrosion and paint and varnish coatings: ultrasonic flaw detectors, pulsed X-ray machines, a device for determining the depth of anti-corrosion impregnation of construction products, an electromagnetic thickness gauge for controlling anti-corrosion coatings, a viscometer for determining the viscosity of paint and varnish materials;

– quality control equipment for ferrous binders, aggregates and asphalt concrete: a viscometer for determining the conditional viscosity, a device for determining the softening point of oil bitumen, a device for determining the degree of compaction of asphalt concrete;

– other control equipment (torque wrenches for controlling bolt tension forces, a device for measuring heat flows through enclosing structures, an electronic wood moisture meter, a psychrometer for determining air temperature and humidity, etc.)

The general management of the development and implementation of an integrated quality management system is carried out by the head of the construction organization (trust, company, construction association). A special quality management service coordinates the work.

TOPIC 10 CONSTRUCTION MASTER PLANS

Questions for theoretical preparation

10.1 Purpose and types of construction master plans.

10.2 General principles of designing construction master plans.

10.3 Design of general site construction master plans.

10.4 Designing an object construction master plan.

10.5 Organization of warehouse facilities.

10.6 Temporary structures for industrial, administrative and sanitary and household purposes.

10.7 Organization of temporary water supply and drainage.

10.8 Organization of temporary power supply.

10.9 Temporary roads.

10.10 Recommendations for the placement of lifting machines and mechanisms on the construction site

10.1 Purpose and types of construction master plans

According to DBN A 3.1-5-2016 "Organization of Construction Production", a construction master plan (construction master plan) is one of the main documents for the organization of construction and production of works, which addresses the issues of rational, economical and safe organization of a construction site.

A construction plan is a general plan of a construction site, which, in addition to existing and planned permanent buildings, structures and utilities, shows temporary construction facilities and indicates the necessary elements of work organization.

A construction site is a land plot allocated for the construction of an agricultural or industrial enterprise, a village in the countryside, a block or a separate object in a city.

Construction facilities include temporary buildings administrative, amenity and sanitary facilities (offices, canteens, workers' rest and heating rooms, cloakrooms, toilets), production facilities (concrete mixing units, workshops, etc.), warehouses, sites for large-scale assembly and storage of structures, roads, networks for supplying construction with energy, water, heat, communication and signalling equipment, transformer substations, lifting mechanisms, etc.

Depending on the stage of construction production at which the construction master plan is developed, there are two types of construction master plans: *site-wide and object-wide.*

Site-wide construction plan is developed by the design organization as part of the construction management project (CMP). The site-wide construction plan covers the entire construction area. It shows in detail the construction facilities intended for servicing the site as a whole, and, on a larger scale, the temporary buildings and structures used in the construction of individual facilities. General site construction plans are usually developed at a scale of 1:1000 or 1:2000.

Construction plan for the object is developed by the general contractor construction organization (or, on its request, by an organization specialising in the production of organizational and technological documentation) as part of the work execution project (WEP).

The site construction plan is a further detail of the general site plan and is developed separately for each facility that is part of the enterprise under construction, settlement or residential area. The object construction plan is usually drawn at a scale of 1:200 or 1:500.

The construction plan is not permanent for the entire construction period, as the production situation at the construction site changes during the construction process, and in some cases, the construction plan is developed for different stages of construction. This is also the case when certain temporary structures, mechanical installations, material warehouses, crane routes, etc. are dismantled after they are no longer needed. Typically, depending on the stage of construction, the construction plan is first designed to cover the preparatory and zero-cycle works, and then for the period of construction of the above-ground part of the facility.

10.2 Principles of designing construction master plans

The main means of developing a construction master plan is variant design. The following principles should be followed when designing construction master plans:

1. The construction master plan is a part of the comprehensive documentation for the construction of facilities, and its solution should be linked to the decisions made in other sections of the project (the adopted organization and technology of works, construction timeframes set out in the calendar plans).

2. Coordination of the construction plan with other sections of the construction management projects, work execution projects, technological and labour process maps;

3. The solution of the construction plan should ensure the most complete satisfaction of the domestic needs of construction workers.

4. Temporary buildings, structures and utility networks should be located on free areas of the construction site and in such places that allow their operation throughout the construction period without moving from place to place.

5. Costs for the construction of temporary buildings and structures shall be minimal, which is achieved through the temporary use of existing and primarily constructed permanent buildings, roads, structures and utility networks for construction purposes.

6. Temporary production buildings and mechanised installations shall be located as close as possible to the places of maximum consumption of their products.

7. Organization of the most rational cargo flows on the site with a minimum number of overloads.

8. Use for production purposes, sanitary and logistical support of construction mainly standard, mobile and prefabricated buildings and structures that provide the possibility of multiple use.

9. Labour protection issues in the development of the construction plan shall be

resolved in accordance with the requirements of the State Building Regulations and other regulatory documents. Particular attention is paid to creating conditions for the safe movement of workers on the construction site, the safe operation of lifting mechanisms, and fire safety. The decisions made must comply with environmental protection requirements.

10.3 Designing site-wide construction master plans

A site-wide construction master plan is developed for the construction of industrial and agricultural production complexes, residential settlements or individual complex buildings and structures. It is the main design document that reflects the decisions taken in the construction management project on the organization and location of construction facilities, preparation and deployment of construction of major facilities, equipping the construction site with assembly machinery and transport, and providing energy and water.

The initial data for the development of a site-wide construction plan are: the general plan of the construction site, data from engineering and economic studies, cost estimates (organizational and technological schemes for the construction of major facilities, data on the use of sources and the procedure for providing construction with energy and water, the availability of the construction company's production facilities and the possibility of using them, a construction schedule, information on the need for major resources with a breakdown by calendar periods, calculations of the volume of demand for.

The general site construction plan consists of a calculation and explanatory note and a graphic part.

The calculation and explanatory note, based on the construction schedule, determines the need for labour, material and technical, and energy resources by periods and stages of construction. Based on the identified need for resources, the types and number of temporary buildings, structures, devices, construction machines and mechanised installations are determined.

The graphic part of the general site budget plan should show: existing and planned permanent buildings, structures and communications with the selection of those used for construction purposes; direction and order of organization of construction and assembly works; placement of the main construction cranes on the construction site, indicating the zones for each of them and taking into account the possibility of their use by all interested organizations, ensuring their normal and uninterrupted operation throughout the construction period; location of temporary buildings for administrative, sanitary, domestic and warehouse purposes; temporary paths and networks of engineering communications with an indication of the places of connection of temporary networks to existing ones.

Power supply, water supply, gas supply and communication schemes should be developed in a comprehensive manner, taking into account all stages of work and subsequent development of construction in the area.

The design of the site-wide construction plan is carried out in the following sequence:

1) on the basis of the calendar plan, determine the need for labour, energy and material and technical resources by construction periods and calculate the volume of temporary buildings, structures and production facilities;

mark the boundaries of the construction site;

2) mark existing and planned buildings, structures and locations, including transport communications and utility networks;

3) locate the main assembly cranes, construction machines and devices, storage areas and areas for the consolidated assembly of building structures and process equipment;

4) design temporary roads and utilities;

5) show the locations of temporary auxiliary and service buildings, structures and installations;

6) provide conventional designations and list (explication) of buildings, structures and installations required for construction needs.

The following technical and economic indicators are used to assess the effectiveness of various construction plan options:

– length and cost of temporary roads;

– specific costs of temporary buildings and structures (as a percentage of the total construction cost);

– duration and labour intensity of works on organization of temporary construction facilities during the preparatory period;

– length and cost of temporary power lines and networks per unit of construction area (1 ha).

In addition to these key technical and economic indicators, the construction plan is assessed in terms of other factors. For example, they assess whether the adopted scheme of temporary roads is suitable for the convenience of transport, the longest distances from residential premises to workplaces, etc.

In cases where organizational and technical solutions cover an area outside the construction site, the development of a site-wide construction plan is preceded by the preparation of a situational plan for the construction area.

The situational plan shows the existing and planned settlements and residential areas; production and logistical facilities; deposits and quarries of local building materials; external road and railway networks; river berths and water intakes; communication and power lines; main water and gas supply lines; and sewerage systems.

The situational plan is prepared on the basis of data obtained as a result of engineering and economic studies and surveys of the natural conditions of the construction area.

Depending on the size of the area covered, the situational plan may be drawn up at a scale of 1:5000, 1:10000, or 1:25000.

10.4 Design of the facility construction master plan

The site construction master plan as part of the project shall be developed for the construction of each individual building (structure) located on the site construction plan.

The site construction master plan, which is designed with a greater degree of detail than the site-wide plan, shows only those temporary buildings, structures, roads, and utilities necessary for the construction of the facility.

The general methodology for designing facility construction plans is usually similar to the methodology used for developing site-wide plans

The initial data for the development of a site construction plan as part of the project for the execution of works (PEW) are a site-wide construction plan as part of the construction management project (CMP); a schedule of works on the site or a grid schedule; process maps; a schedule of movement of personnel on the site; a schedule of delivery of building structures, products, materials and equipment to the site; schedule of movement of main construction machines on the site; solutions for the installation of temporary engineering networks; energy requirements; list of temporary buildings and structures with the calculation of the need; solutions for labour protection, environmental protection and fire protection measures, as well as working drawings and estimates for the site.

The site construction plan, like the general site plan, consists of a calculation and explanatory note and a graphic part.

The calculation and explanatory note contains: refined calculations of cellars in administrative and amenity spaces, production and service facilities, energy, water and heat supply, telephony; specific solutions for the selection of construction cranes and stationary lifting units. When calculating the need for construction machines, the volume of construction and installation work, the size and configuration of the building under construction, the largest weight of the structures to be installed, and the capabilities of the contracting construction organization are taken into account.

The graphic part of the site construction plan contains the same elements as the general site plan, with clarification of previously made decisions.

The site construction plan shows construction site boundaries and the type of fencing; existing permanent and temporary buildings and structures, main machinery and lifting equipment, their locations and areas of operation; permanent and temporary pedestrian and motorways; traffic patterns; existing, planned and temporary utility networks and communications with indication of their connection points to power sources; entrances and exits to the construction site; entrances to the facility under construction; hazardous and assembly areas; means of lighting the construction site, work area, passages and aisles, storage areas for materials and structures; consolidated assembly areas; fire hydrants and other fire extinguishing equipment with access to them; geodetic surveying base signs.

The sequence of designing the facility construction plan is mostly the same as the site-wide construction plan, but additional requirements to the facility construction plan as the main working document for construction and installation works are taken into account. For example, the amount of resources required for the construction of a facility is taken from other sections of the project, where they are determined not by aggregate indicators, but by physical volume, number of workers, and are taken according to the construction schedule for that facility, etc.

The main decisions of the facility construction plan are determined primarily by the location of lifting mechanisms, so it is advisable to start its design by determining the required number of cranes and their locations, with the dimensions, routes, work areas, and fencing of the routes indicated. When tower cranes are used, crane access routes are marked on the construction plan, and for self-propelled jib cranes, the axes of their movement and parking during work. After that, on-site warehouses are marked on the construction plan. At the same time, at the storage areas, the dimensions of which are defined on the site-wide construction plan, it is necessary to show the placement of prefabricated structures by type and brand, to accurately indicate the place for certain materials, indicating the necessary tie-ins and dimensions. Building structures and products must be placed in the crane's operating area in accordance with the work technology.

After placing the warehouses, proceed to marking the temporary buildings and structures required for the construction of the facility, access roads, temporary power, water, sewerage networks, etc.

The site construction plan specifies the health and safety requirements.

10.5 Organization of warehouse management

For construction organizations to operate smoothly, they need to have a continuous supply of appropriate building materials, structures and products. Such conditions can be created by ensuring certain stocks of the necessary materials in special warehouses.

The size of production stocks depends on many factors, including the technology and organization of work (off-the-shelf or on-site installation), daily material consumption, frequency of delivery, batch size, mode of transport, local conditions, etc. Large stocks of materials increase the reliability of uninterrupted operations. However, increased stocks of materials also increase the need for working capital and warehouse space. This causes additional costs for warehouse equipment and warehouse operations. Therefore, construction organizations need to ensure that their warehousing facilities are properly managed to keep stocks to a minimum, but sufficient to ensure the rhythmic operation of all departments and teams of workers on the construction site.

When developing a construction plan as part of a construction management project (CMP) and a project for the execution of works (POW), it is advisable to design warehouses in the following sequence:

– determine the stocks of resources to be stored in warehouses;

– select a storage facility (open, closed or other);

– calculate the areas by type of storage;

– select types of warehouses;

– place and link warehouses on the site;

– place parts in open warehouses.

The amount of material stocks can be determined by time in kind or in money.

When developing a construction management project (CMP), the amount of materials to be stored is determined by the following formula

$$P_{stock} = P_t \cdot H \cdot K_1 \cdot K_2, \quad (10.1)$$

where P_t is the total amount of materials and products required;

Tn – construction duration according to the calendar plan, days;

H – stock rate of a certain type of materials at the construction site, days;

K_1 – coefficient of unevenness of materials supply to warehouses, taken for water transport – 1.2; railway and road transport – 1.1;

K_2 – coefficient of unevenness of material consumption; is assumed to be 1.3.

During the development of work execution project (WEP), the amount of materials to be stored is determined by formula (7.1), but the calculation is made depending on the accepted pace of work in accordance with the needs for a particular structural and technological part of the building (sections, areas). In industrial construction, this is a span, tier, floor, etc., in civil construction - a floor, section. If installation is carried out directly from vehicles, only small-sized products and auxiliary materials are stored. The stock of such materials is assumed to be equal to the demand for one or more sections.

10.5.1. Calculating the need for warehouse space

The calculation of the area of temporary warehouses on a construction site depends on the method of storing materials and their quantity. The area of a temporary warehouse consists of determining its usable area, which is used directly for storing materials, as well as the auxiliary area of receiving and delivery areas, taking into account passages and aisles.

The method of calculating the area of temporary warehouses depends on the design stage. During the development of a construction management project (CMP), the estimated warehouse area is determined as follows:

For basic materials and products, the useful area of the warehouse is calculated using the following formula:

$$S_p = P_{stock} \cdot q, \tag{10.2}$$

where R_{stock} is the estimated stock of materials in physical terms;

q - standard area per unit of stored material.

For other materials and products, the calculation is based on the norms per 1 million UAH of the annual volume of construction and demolition works by the formula

$$S_p = S_s \cdot C_{ciw}, \tag{10.3}$$

where S_s is the standard area, m2/million UAH, of the cost of construction and installation works (CIW);

C_{ciw} – annual volume of construction and installation works (million UAH), determined according to the calendar schedule of the facility construction.

When developing a project for the execution of works (PEW), the area of open warehouses is calculated in detail, based on the actual dimensions of the stored materials and coefficients that take into account passages, aisles and auxiliary rooms in compliance with safety and fire requirements.

The total area (m^2) is calculated by the formula

$$S_{tot} = \sum k_n \cdot S_p \,, \tag{10.4}$$

where k_n is the coefficient that takes into account passages, aisles and auxiliary rooms (for open storage of materials in bulk, k = 1.15-1.25, in stacks – 1.2- 1.3, in vaults and bunkers – 1.3-1.4; for universal warehouses - 1.5-1.7);

S_p is the actual area of the stored resource.

10.6 Temporary structures for industrial, administrative and sanitary purposes

In order to ensure construction and installation works and create appropriate working conditions, a set of temporary industrial, administrative and sanitary buildings is placed on the construction site. Such temporary buildings are constructed only for the construction period.

Unlike permanent buildings, temporary structures have their own peculiarities related to their use, design solutions, methods of construction, operation and financing.

The composition, number and need for production areas are determined on the basis of the scope of the relevant types of work, design standards for preparing construction projects, the degree of factory readiness of products delivered to the construction site, and the nature of the work performed.

The need for temporary administrative and sanitary facilities is calculated as follows:

- determine the number of workers, ETS and employees at the construction site;
- compile a list of required inventory buildings and structures;
- determine the required areas and volumes of inventory buildings and structures;
- select the type and design of inventory buildings and structures;
- draw up a title list of inventory buildings and structures required for placement on the construction site.

The construction need for administrative and sanitary facilities is determined from the estimated number of personnel. The estimated number of workers on the construction site during the development of the construction plan as part of the construction management project (CMP) is determined by the annual output according to the formula

$$N_w = C \cdot K_1 \cdot K_2 / (B \cdot T), \qquad (10.5)$$

where C is the cost of construction, installation or special works for the calculation period, UAH;

B – average annual output per employee, UAH/man-day;

T is the duration of the work of the settlement period according to the schedule, days;

K_1 – coefficient that takes into account the uneven use of labour resources at the facility (1.6-1.8);

K_2 is a coefficient that takes into account holidays, sickness, etc. (1.6).

In the calculations, the number of employees is taken from the largest shift. The area of temporary buildings when designing the construction plan as part of the PDD is determined based on the maximum number of employees employed during a shift at the construction site.

The estimated number of workers at the construction site is determined by the labour intensity of construction and installation works by the formula

$$Np = Q \cdot K_1 \cdot K_2 / T, \qquad (10.6)$$

where Q is the labour intensity of construction and installation works for the settlement period, man-days;

T – duration of the settlement period in working days (determined by the calendar or grid schedule);

K_1 – coefficient that takes into account the uneven use of labour resources at the facility (1.6-1.8);

K_2 – a coefficient that takes into account holidays, sickness, etc. (1.6).

The proportion of certain categories of employees (workers, engineering and technical staff (ETS), employees, ILOs, fire and security guards) is taken as an approximation depending on the indicators of a particular construction industry within the following range: workers - 83%; ETS - 8-13%; employees - 3-5%; ILOs and security guards - 1-2%. For calculations where there are no specially defined production conditions, the ratio of men to women working is roughly 0.7 and 0.3.

Given the number of employees, the area of temporary buildings is calculated according to the norms of need per employee or the design capacity of inventory temporary buildings. The design capacity of inventory buildings is determined based on their availability in construction organizations or from catalogues of temporary buildings. The area of mobile temporary buildings is determined by reference. The area of administrative and sanitary facilities is calculated by the formula

$$S = N_p \cdot S_n , \qquad (10.7)$$

where N_p is the estimated number of construction personnel for a given type of building, persons;

S_n is the standard area indicator for each type of building depending on their nomenclature, m^2/person.

Standard indicators of the need for space in offices (foremen's rooms), control rooms, personnel offices, checkpoints and other administrative buildings depend on specific construction conditions and are 3-7 m^2/person.

The normative indicators of the need for areas of sanitary buildings and structures are adopted in accordance with DBN A.3.1-5:2016 Organization of construction production

The decision on the location of temporary industrial, administrative and sanitary facilities on the construction site is made by the designers of the construction plan together with construction organizations that perform certain construction, installation or special works at the facilities during the period for which the construction plan is being developed.

When erecting temporary buildings, the following basic requirements should be taken into account:

– the location of buildings should ensure safety and convenient access for workers;

– temporary buildings should not interfere with the construction of the main facilities during the entire design period, especially for prefabricated and non-inventory buildings;

– locations should ensure minimal costs for connecting to utilities in the following order of preference: sewerage - heat supply - water supply - electricity supply - telephony;

– it is necessary to ensure maximum blocking of inventory buildings by functional groups;

– temporary buildings are allowed to be located no further than 25 metres from fire hydrants and roads.

Temporary premises and buildings on the construction plan are located on plots that are not subject to development of major facilities. Administrative and sanitary buildings can be located in three ways: dispersed (buildings are located throughout the construction site); nodal (buildings are concentrated in a specially designated area for a number of construction organizations) and mixed (buildings are located in residential camps to serve all categories of employees working at the site, especially for large industrial complexes). Residential camps are constructed before the start of production of the main construction materials at the facilities. They are equipped in accordance with the construction management project (CMP) and the work execution project

(WEP), sanitary and fire safety rules, applicable standards and the approved nomenclature for sanitary and amenity services for construction workers. The construction management design (CMD) determines the size of the site for the camp, the layout of buildings and the means of supplying them with electricity, water and other resources. The design of the project for the execution of works (PEW) specifies a set of buildings by type and specifies how they will be connected to utilities.

Residential camps are located on the planned territory with maximum proximity to the main routes of movement of workers at the facility, in a safe zone from crane operation. They should be located so that they do not interfere with construction during the entire design period.

Administrative premises (offices, control rooms, etc.) are located at the entrance to the construction site. Sanitary and amenity buildings (cloakrooms, showers, drying rooms for clothes and shoes, etc.) are located in accordance with the hazardous areas, the boundaries of which are set in accordance with the requirements of DBN A.3.2-2-2009 System of Labour Safety Standards. Labour protection and industrial safety in construction. The main provisions (NPAPP 45.2-7.02-12) at a distance of at least 50 m from objects that emit dust, harmful vapours and gas (bunkers, concrete and mortar units, etc.) on the leeward side of the prevailing direction. Heating rooms should be located no further than 150 metres from workplaces. The distance from workplaces to catering facilities should be no more than 500 m. Medical stations are located in one of the blocks (containers) of the amenity space, the distance to the most distant workplaces is 600-800 m. Toilets with a drain should be located near sewer wells. In the absence of the latter, mobile toilets with sealed containers are used. Toilets with cesspools can be used only with the permission of the sanitary authorities. Toilets outside buildings should be located no further than 100-200 m from the most remote workplace.

All temporary buildings on the construction plan are numbered according to their specificity, with their reference to the coordinate grid or to objects already linked to it (buildings, roads, etc.), and the supply lines of networks and communications are shown.

10.7 Organization of temporary water supply and sewerage

Water on a construction site is used for production, domestic and firefighting purposes.

The design of temporary water supply is carried out in the following sequence: identify water consumers and determine the estimated water demand for all consumers; establish water quality requirements; select a water supply source; outline the network layout; calculate pipeline diameters; and link the route and facilities on the construction plan.

The source of water for temporary construction water supply can be a permanent (designed) water supply system, which is constructed primarily during the preparatory period of construction. If it is not possible to obtain water from a permanent water supply system, natural open water reservoirs (rivers, lakes) or artesian wells are used.

The main initial data for determining the estimated water demand are:

– nomenclature, scope, timing and means of construction and installation works

– construction and installation works;

– number of workers employed at the construction site;

– data on water supply sources;

– regulatory and reference literature.

When developing site-wide construction plans as part of a construction management project (CMP), the amount of water consumed, excluding the need for firefighting water, is calculated using aggregate indicators per unit of the estimated annual cost of construction and installation works by the formula

$$Q = B \cdot n \cdot K, \qquad (10.8)$$

where B – annual volume of construction and installation works in monetary terms;

n – estimated water consumption per unit cost of construction and installation works;

K is a coefficient that takes into account changes in the estimated cost of construction depending on the construction area (for Ukrainian regions, K = 0.97-0.99).

When developing site construction plans as part of a project for the execution of works (PEW), water consumption is calculated for each consumer separately using the following formulas for production needs:

$$Q_{prod} = 1,2 \cdot q_в \cdot n_в \cdot K_1/(3600 \cdot t), \quad (10.9)$$

where 1.2 is the coefficient of unaccounted water consumption;

q_c – specific water consumption for production needs;

n_c – number of production consumers (plants, machines, etc.) in the busiest shift;

K_1 – coefficient of hourly irregularity of water consumption (average 1,5);

t – number of hours taken into account in a shift; 3600 - number of seconds in one hour.

– for household needs:

$$Q_{hous} = q_г \cdot n_р \cdot K_2/(3600 \cdot t) + q_д \cdot n_д/(60 \cdot t), \quad (10.10)$$

where q_g is the specific water consumption for household needs (15 litres per employee per day for sites without sewage and 25 litres for sites with sewage);

q_d – water consumption for showering by one worker (30 litres per shift);

n_e – number of employees in the busiest shift;

n_d – the number of employees who use the shower (40% of the total number);

t – duration of use of the shower unit (45 minutes);

K_2 is the coefficient of hourly irregularity, taken from the following data:

– construction works -1.5;

– power plants -1.1;

– auxiliary enterprises - 1.25;

– transport facilities - 1.5-2;

– household and drinking water consumption directly on the construction site - 3;

– canteens - 1.5;

The water consumption for external fire extinguishing for the construction period is based on the simultaneous action of two hydrant flows of 5 l/s each, i.e. Q_{fire} = 10 l/s. Such flow rates are accepted for construction projects with a building area of up to 10 hectares; for projects with a building area of up to 50 hectares, the water consumption is 20 l/s.

The total estimated water consumption is calculated by the formula

$$Q_p = Q_{prod} + Q_{hous} + Q_{fire}. \qquad (10.11)$$

The schematic diagram of a temporary water supply network that comprehensively meets domestic, industrial and fire-fighting needs can be adopted as a ring, dead-end or mixed system. If necessary, the drinking water supply is separated into an independent system.

At least two hydrants shall be provided on the water supply network, located at a distance of no more than 150 m from each other, at a distance of 2.5 m from the edge of the carriageway.

The diameter of the pipes of the water supply pressure external network is determined by the formula, mm:

$$D = \sqrt[2]{\frac{Q_p * 1000}{3{,}14 * v}} \quad , \qquad (10.12)$$

where Q_p is the calculated water flow rate, l/s;

v – water velocity in the pipes (for small diameters, 0.6-0.9 and for larger diameters from 0.9 to 1.4 m/s).

If an existing permanent water supply system is used for temporary water supply, a combined system is designed to meet production, domestic and fire-fighting needs. In cases where open water reservoirs are used as sources, industrial and firefighting water supply is separated into a separate system, and drinking water is delivered to the construction site in special tanks.

A temporary water supply network is designed after all water consumers have been identified on the construction plan. It should be borne in mind that a dead-end temporary water supply network is shorter and less reliable in operation than a ring water supply network, as in the event of damage to any part of it, all water consumers are cut off. The ring network is more advanced in terms of uninterrupted supply to all consumers, but it is longer and more expensive to construct than the dead-end network. The mixed water supply network is a looped network with dead-end branches from it to the places of water consumption.

The nature and depth of the temporary water supply pipes is determined by the operational characteristics of the construction area and the time of year when the water supply system will be operated. During construction in summer, temporary water supply can be laid on the ground surface, embedded in places of high traffic flow in the ground or placed on poles.

Wastewater generated at the construction site should be directed as follows: domestic wastewater from temporary sanitary facilities - to the external network of household faecal sewage; industrial wastewater from construction machines and technological processes - to special settling tanks, and then, after clarification, to the external network of rainwater sewage.

Temporary sewerage systems are set up or existing sewerage networks near the construction site are used for construction purposes. In some cases, a sewerage network is constructed in advance, as provided for in the design of the facility under construction, to be used for construction needs.

When designing temporary sewerage systems, they are equipped with outlets, wells, sumps, cesspools, etc. The diameters of the outlets are designed to be at least 50 mm. The length of the wastewater outlets from the places of creation is provided at $\varnothing$ = 50 mm no more than 10 м, and at $\varnothing$ = 100 mm no more than 15 м.

10.8 Organization of temporary power supply

10.8.1 Power supply to the construction site

The main type of energy on a construction site is alternating current electricity. It is used for:

– power supply to power plants (electric excavators; mortar units; tower, gantry and bridge cranes; lifts and other small continuous transport mechanisms; compressors, pumps, fans);

– production (technological) needs (electric welding transformers; transformer electric heating of concrete and other building materials, soil, pipelines, etc;)

– external lighting (lighting of the construction site in the area of work, main and secondary passages and driveways, work sites, warehouses; emergency, evacuation and security lighting);

– internal lighting (offices, sanitary and public premises, places of internal work, warehouses and offices, evacuation lighting).

Electricity sources at construction sites are transformer substations (TS) of stationary (permanent) or mobile (temporary) types. Stationary transformer substations are constructed during the preparatory period of construction and are designed to have a capacity of 10 to 1800 kV-A. Mobile substations are used at facilities that do not have a permanent power supply.

Transformer substations or distribution substations convert AC electricity of 35, 10 or 6 kV into safer electricity of 380 or 220 V. The voltage of 380 V is used to power power plants, while the voltage of 220 V is used for lighting and powering small electrical tools.

The design and organization of power supply for a construction site begins with determining the design load, i.e. the amount of electrical power required by the transformer substation. There are several calculation methods. For general indicative calculations, methods based on averaged actual data on power consumption (per 1 million UAH of annual construction and installation works (CIW)) are used. The total electricity demand (Pd) at the stage of development of the construction management project (CMP) is determined as the estimated transformer capacity (kV-A) based on the maximum annual volume of construction and installation works at the facility:

$$P_p = p \cdot C_{annual} \cdot k, \quad (10.13)$$

where p is the specific capacity of kV-A/million UAH (determined by regulatory indicators);

C_{annual} is the annual volume of construction and installation works, million UAH (determined by regulatory indicators);

k is a coefficient that takes into account the change in the estimated cost depending on the construction area (taken according to the calculated standards. For most regions of Ukraine, k = 0.83-1.02).

The maximum annual volume of construction and installation works at the facility (CIW) at the stage of development of the construction management project (CMP) is determined based on the proposed construction organization in accordance with the work schedule. It is determined depending on the total cost of construction and installation works on the object and the construction duration recommended by the standards.

Based on the determined value of the total design capacity, the required common transformer substation is selected, consisting of one or more suitable serial transformers.

Lighting of construction sites and workplaces is carried out in accordance with DSTU 8828:2019 Fire safety. General provisions as working, emergency, evacuation and security lighting.

The construction site lighting project should be developed as part of the project of work execution (PWE) in accordance with the standards for construction site lighting DSTU 8828:2019 Fire safety. General provisions. The design involves determining the cellar lighting, selecting and arranging light sources, and calculating the power required to supply them.

The number of floodlights n to be installed to create the required illumination on the area S $E_r = k \cdot E_n$, (where k is the safety factor; E_n is the standard illumination) is calculated by the formula

$$n = m \cdot E_p \cdot S / P_l, \tag{10.14}$$

where m is a coefficient that takes into account the light output of light sources, the efficiency of floodlights (taken according to standards);

P_l is the power of floodlight lamps, W (taken from the standards).

When determining electricity consumption for indoor and outdoor lighting, specific power indicators can also be used in accordance with DBN A.3.1-5:2016 Organization of construction production.

In urban areas, the choice of electricity sources for temporary power supply of a construction site is usually made by connecting to the municipal power grid. If it is not possible to connect to the municipal power grid, mobile inventory power plants are used, which are placed in places where consumers are concentrated.

Installation and operation of lighting networks is carried out by the chief power engineer of the construction department (CD). Sometimes these functions are entrusted to a specialised electrical installation department or to highly specialised firms that perform the entire cycle of work: design, installation, operation and subsequent dismantling of the outdoor lighting system. Such firms have appropriate fleets of mobile lighting units mounted on tractor trailers, cars, and motor vehicles; if necessary, they also use mobile diesel generator sets.

The construction site must comply with the conditions for the binding and placement of transformer substations, power and lighting networks, as well as electrical safety standards in accordance with DSTU B A.3.2-13:2011 System of Labour Safety Standards. Construction. Electrical safety. General requirements (GOST 12.1.013-78, MOD). Temporary power grids on the construction site should be placed on poles; in the areas of crane operation, at road intersections, it is possible to use cable wiring of power grids. It is advisable to place the transformer substation in the centre of the electrical loads with a radius of 400-500 m.

The amount of electricity consumed at the construction site as a whole, as well as at individual sites, is determined by meters installed in transformer substations. In today's environment, with rising electricity prices, reducing electricity consumption is a significant factor in overall savings in the organization of construction work.

10.8.2 Supplying the construction site with other types of energy resources

The necessary capacities and sources of supply of compressed air, heat, gas, etc. to the construction site are determined in the development of relevant projects, in accordance with DBN A.3.1-5:2016 "Construction Production Organization". The construction management project (CMP) defines only general solutions for supplying the construction site with these energy resources based on calculations using aggregate indicators per UAH 1 million of the annual cost of construction and installation works. The project is refined and detailed during the development of the project of work execution (PWE) by taking into account each consumer using methods similar to determining the required capacity in electricity.

Heat at the construction site is used for: technological needs in winter (heating water and aggregates at concrete units, heating of hotbeds, heating of concrete, etc.); heating and drying of objects under construction; heating and ventilation and hot water supply of temporary sanitary and administrative buildings (showers, canteens, locker rooms, offices, etc.).

The sources of temporary heat supply are existing or planned heating networks, boiler houses of the district under construction, enterprises or combined heat and power plants (CHP). The best option for supplying heat to a construction site is to use permanent heating mains. Temporary heat supply systems are usually designed for the construction period only and are subject to dismantling upon completion of construction. They are designed in a dead-end pattern, less often in a ring pattern. In winter, the heating system provided for by the project is used to heat buildings under construction. Sometimes air heating is used, supplying warm air through ducts from steam or gas heaters.

The heat demand is calculated separately for each consumer based on the maximum hourly consumption during the heating period using the formula

$$\theta_1 = k_1 * k_2 * \Sigma\theta'_{1,} \qquad (10.15)$$

where θ′1 is the heat demand of the i-th group of buildings;

k_1 is a coefficient that takes into account heat losses in networks (equal to 1.1-1.5);

k_2 - coefficient for unaccounted heat losses (equal to 1.1-1.2).

The total heat demand is determined by the formula

$$\theta = \theta_1 + \theta_2 \qquad (10.16)$$

where θ_2 is the heat demand of technological processes (water heating, steam heating of concrete structures, frozen ground heating), determined by heat engineering calculations or taken from reference books.

Compressed air on a construction site, they are used for:

– driving pneumatic tools (punchers, jackhammers, concrete breakers, rammers, stoning tools, painters, etc.)

– performing construction work (loosening frozen ground, driving piles, etc.)

– supply of concrete mix and mortars through pipelines, movement of cement through air ducts, blowing (cleaning) of formwork of monolithic reinforced concrete and concrete buildings.

Calculating the compressed air demand of a construction site includes: identifying consumers, their total consumption, selecting a resource supplier and drawing up a compressed air supply scheme.

The total compressed air demand is determined by the formula

$$E = \Sigma f_i \cdot n_i \cdot k_i, \qquad (10.17)$$

where f_i is the compressed air consumption by the i-th mechanism, m^3/min;

n_i – number of homogeneous mechanisms;

k_i, is the coefficient that establishes the simultaneous operation of the mechanisms (equal to 0.85-1.4 for two mechanisms, 0.8 for six, 0.7 for ten, 0.6 for five, 0.5 for twenty).

The power of the compressor unit (N) is determined by the formula

$$N = m \cdot \Sigma q \cdot k_o, \qquad (10.18)$$

where q is the air demand of each tool, m^3/min;

m is a coefficient that takes into account the air consumption in pipelines and tools (equal to 1.3-1.5);

k_o is a coefficient that takes into account the simultaneous operation of tools.

To meet the needs of the construction site in compressed air, mobile compressor substations with a capacity of 5-10 m^3/min are used, usually located directly near the places of consumption and work, or stationary stations located in prefabricated buildings with a capacity of 40 m^3/min.

10.9 Temporary ways

To ensure the uninterrupted delivery of structures, materials, machinery and equipment to the construction site at any time of the year and regardless of weather conditions, it is necessary to have convenient access and routes for internal transport on site. Most construction sites deliver goods primarily by road. Roads are of two types: permanent and temporary.

Permanent roads are constructed after the territory has been vertically levelled, drainage, gutters and other utilities have been installed. When designing permanent roads that are used during construction, it is necessary to take into account the compliance of the road structure with the loads generated by the movement of vehicles and tracked machines.

Permanent roads do not always fully support construction due to the discrepancy between the route and dimensions. In such cases, temporary roads are constructed simultaneously with the permanent roads intended for construction vehicles. Temporary roads are the most expensive part of temporary structures. The design of the road depends on the traffic volume, type and weight of vehicles, soil bearing capacity and hydrogeological conditions, and is ultimately determined by economic calculations.

The design of the on-site road network is based on the geodetic basis of permanent transport communications and their use for construction purposes. Temporary roads can be: unpaved, profiled, crushed stone, slag with a top layer of asphalt or surface treatment with binders, precast concrete inventory slabs. Temporary roads are designed to accommodate the traffic volume and intensity of traffic, taking into account the order of construction.

Profiled roads are constructed for low traffic volumes (up to 3 vehicles per hour in one direction) under favourable soil and hydrogeological conditions. To drain water from rainfall and snowmelt, the roadway is profiled. Such roads can be constructed in the shortest possible time and at the lowest cost.

Dirt roads that have to withstand heavy loads or are located in less favourable conditions are strengthened with gravel, slag, clay firing, cement, etc. Temporary roads for a load capacity of 12 tonnes per axle are best constructed from precast concrete slabs. The slabs are laid on a sandy underlying layer. The thickness of the sand layer depends on the subgrade soil group and the degree of moisture (usually 10-25 cm).

All buildings under construction and operation, including temporary buildings, shall be provided with free access for vehicles and fire trucks. Buildings with a width of more than 18 m should have access from two sides, and buildings with a width of more than 100 m should have access from all sides. Construction roads are usually designed as circular and should have at least two entrances (exits). The width of the gates of road entrances (exits) shall be based on the largest width of construction machines and vehicles with an addition of 1.5 m, but not less than 4.5 m; for railway entrances - not less than 4.9 m. In dead-end areas, entrances and turning areas of 12x12m are provided for turning vehicles or loop detours. The maximum width of the roads is 3.5 m for one-way traffic and 6 m for two-way traffic. The width of the carriageway of transit routes is taken into account the size of the road slabs: single-lane - 4.5 m, two-lane - 8 m.

In case of using smaller widths of permanent roads for construction purposes, they can be temporarily widened to the required dimensions with inventory reinforced concrete slabs. In case of one-way circular traffic on roads, 6 m wide and 12-18 m long areas for vehicles to pass each other should be arranged in the visibility zone at least 100 m apart. The same areas shall be arranged in the areas of unloading materials regardless of the traffic pattern.

The radius of curvature of the tracks in the plan is 30 m for the transport of long structures at a vehicle speed of 15-20 km/h, and the widening of the carriageway with curves; for temporary tracks, a curve radius of at least 12 m is allowed.

The distance from the edge of the carriageway to the construction structures should be taken in accordance with DBN A.3.1-5:2016 Organization of construction production.

The distance between the road and the storage area is assumed to be 1.0÷0.5 m. The road running along the pit should be located outside the collapse zones.

The intersection of roads with railways shall be made at an angle of 60 to 90° with crossings with counter rails, special signs and lighting. Roads on both sides should have a hard surface with a slope of more than 5%.

Sidewalks arranged on the construction site shall be placed along the roadways at a distance of 2.0 m from their edge. The width of the sidewalks should be at least 1.5 m.

The temporary road should be located no closer than 8-12 m from the building under construction.

Roads and pedestrian paths should be located outside the hazardous areas. In the areas of operation of cranes, paths must be arranged in compliance with the labour protection rules and regulations DBN A.3.2-2-2009 System of Labour Safety Standards. Labour protection and industrial safety in construction. Basic Provisions (NPAPP 45.2-7.02-12) with the installation of barriers and warning signs at the entrances to hazardous and installation areas, and the installation of signal fencing.

On the construction master plan, arrows indicate the directions of traffic, entrances and exits, places of unloading and loading, railway crossings, barriers, hazardous areas, track widths, curve radii, and permissible approach distances to buildings.

10.10 Recommendations for the placement of lifting machines and mechanisms on the construction site

The placement of lifting machines on the construction site is determined by the accepted technology and organization of the construction of buildings and structures. These machines are tied down during the design of construction master plans, which are part of both the construction management project (CMP) and the work execution project (WEP), taking into account the restrictions and requirements of labour protection standards and rules at the construction site.

Tying down the selected cranes is performed in the following sequence:

1) tie cranes to the axes of the building under construction or reconstruction;

2) determine the size and location (in plan and vertical) of assembly and hazardous areas;

3) determine the operating conditions of cranes, taking into account applicable restrictions;

4) determine additional measures to ensure the safe operation of cranes on construction sites.

When designing for the placement of lifting machines on construction sites, it is necessary to consider:

– dimensions and configuration of buildings (structures), their underground and above-ground parts:

– parameters and location on the building plan of the structures to be installed, their weight and dimensions;

– installation methods and technologies used;

– soil and climatic factors, design features of the underground part of the building;

– the degree of crowding of buildings being erected on the construction site;

– restrictions on the placement of cranes near existing buildings (structures), sites and storage facilities for materials and structures, as well as sites for the consolidated assembly of structures;

– joint operation of several cranes at one site;

– location of roads, underground and overhead utilities.

Taking into account the dimensions and configuration of buildings and structures, the methods and ways of feeding the structures to be installed in the crane service area and at the workplace are determined. One of the main factors that must be taken into account is maintaining the pace of work.

The installation of machines on a construction site should provide space sufficient for the crane operator to view the working area and manoeuvre as required during installation.

Lifting machines should be installed in such a way that when lifting loads, there is no need for preliminary pulling (when the load ropes are inclined) and it is possible to move the lifted loads at least 500 mm above buildings, structures, stacks of goods, sides of rolling stock, etc. encountered along the way.

The horizontal distance between the structures to be moved and protruding parts of buildings, equipment, stacked materials and structures should be at least 1.0 m.

In this case, when the lifting machine is moving on ground rail tracks, the following requirements must be observed:

– the horizontal distance between the protruding parts of the crane and buildings, stacks of goods and other objects located up to 2.0 m above ground level or working platforms must be at least 700 mm, and at a height of more than 2 m - at least 400 mm;

– the vertical distance from the counterweight console or from the counterweight placed under the tower crane console to areas where people can be present must be at least 2.0 m;

The installation of cranes for construction and installation works should be carried out in accordance with the project of work execution (PWE), and cranes moving along rail tracks in the security zone of an overhead power line should be additionally agreed with the owner of this line.

Installation and operation of jib cranes at a distance closer than 30 m from the outermost wire of a power line or overhead power line with a voltage above 36 V may be carried out only under a work permit that determines the safe conditions for performing such work.

When working under unconnected contact wires of public electric transport, the distance between the crane boom and the wires must be at least 1.0 m.

Self-propelled jib cranes must be installed on a planned and prepared construction site, taking into account the category and nature of the soil, so that during their operation the distance between the rotating parts of the cranes and buildings, structures and other objects is not less than 1.0 m. It should be remembered that it is strictly forbidden to install cranes on freshly poured, unconsolidated soil, as well as on sites with a slope greater than that specified in the crane's passport.

Questions for self-examination:

1. What is the purpose of construction master plans? Name their types.

2. Give an example of the general principles of designing construction master plans.

3. What is the difference between the design of general site construction master plans and the design of an object construction master plan?

4. What is the organization of warehousing?

5. What are temporary structures for industrial, administrative and sanitary purposes?

6. How is the organization of temporary water supply and sewerage carried out?

7. How is temporary power supply organised?

8. Name the main recommendations for the placement of lifting machines and mechanisms on the construction site. What are temporary roads?

LIST OF RECOMMENDED SOURCES OF INFORMATION

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КОНСПЕКТ ЛЕКЦІЙ

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