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УДК 629.5.081.326

METHODS OF IMPROVEMENT OF THE DESIGN AND CONSTRUCTION TECHNOLOGY OF COMPOSITE DOCKS

ПУТИ УСОВЕРШЕНСТВОВАНИЯ КОНСТРУКЦИИ И ТЕХНОЛОГИИ СТРОИТЕЛЬСТВА КОМПОЗИТНЫХ ДОКОВ

DOI 10.15589/SMI20180204

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Abstract. The article renders the research based on the use of criteria for choosing the optimal design of a composite floating dock taking into account current standard requirements, which enable developing recommendations for the design and construction technology of the dock. There is substantiated the choice of the main parameters that make it possible to draw a generalized criterion for choosing the optimal designs of floating composite docks with account for the best practices of their construction and operation, as well as the results of experiments in the most difficult docking conditions. The system of criteria is used for controlling the mass and strength of dock structures, a set of technical and economic issues, reliability and ease of operation. A design of a composite floating dock with a reduced number of pontoon frames is proposed. There, the reinforcement aiding local strength is installed on the outside in the direction of the smallest span, and the reinforcement aiding general strength is installed inside the element. Special features of installing the frames in the top deck of the dock are described, and their absence in the concrete towers of the ribs of floor plates and beams is substantiated. The structural and technological diagrams of the constructive midship frame of a floating dock and the slipway for dock construction are presented. Their application allows reducing the material capacity and labour intensity of dock construction. The technological recommendations for reinforcement of bottom plates of the pontoon of a composite floating dock are rendered. The diagram of reinforcement of pontoon bottom plates in the area of maximum hydrostatic pressure is presented. It is shown that a protective layer of concrete on the working reinforcement provides for the joint operation of reinforcement with concrete at all stages of operation of the facility, as well as protection against aggressive external effects. Special features of the selection of a shipbuilding concrete targeted at the extreme conditions of operation of marine reinforced concrete facilities are listed. The influence of air-entraining and plasticizing agents in the concrete mixture is considered. They are used for the improvement of strength, impermeability, frost and corrosion resistance of concrete, reduction of water consumption, enhancement of workability and reduction of consumption of cement.

Keywords: composite floating dock; reinforced concrete pontoon; dock construction.

Анотація. Наведені дослідження на основі використання критеріїв вибору оптимальної конструкції з урахуванням діючих нормативних вимог, які дають можливість розробити рекомендації щодо конструювання і технології побудови композитного плавучого дока Обгрунтовано вибір основних параметрів, які дозволяють побудувати узагальнений критерій для вибору оптимальних конструкцій плавучих композитних доків з врахуванням досвіду їх будівництва та експлуатації, а також результатів експериментів у найбільш важких умовах докування. Подано використання системи критеріїв для контролю маси і міцності конструкцій дока та комплексу питань техніко-економічного характеру, надійності й зручності експлуатації. Запропоновано конструкцію композитного плавучого дока зі зменшеною кількістю набору в понтоні, в якому арматура, що працює на місцеву міцність, установлюється ззовні в напрямку найменшого прольоту, а арматура, що працює на загальну міцність, установлюється всередині елемента. Описано особливості встановлення набору в топ-палубі дока та обґрунтовано відсутність їх у бетонних баштах шпангоутів флорів і бімсів. Подані конструктивно-технологічні схеми конструктивного мідель-шпангоуту плавучого дока та стапеля для побудови композитних плавучих доків, використання яких дозволяє зменшити матеріалоємність та знизити трудомісткість побудови дока. Наведені технологічні рекомендації армування днищевих плит понтона композитного плавучого дока. Подано схему армування днищевих плит понтона в районі сприйняття максимального гідростатичного тиску. Показано, що захисний шар бетону для робочої арматури забезпечує спільну роботу арматури з бетоном на всіх стадіях роботи конструкції, а також захист від агресивних зовнішніх впливів навколишнього середовища. Наведені особливості вибору суднобудівного бетону, орієнтованого на екстремальні умови роботи морських залізобетонних споруд. Розглянуто вплив повітровтягувальних та пластифікуючих домішок у бетонній суміші на поліпшення міцності, непроникності, морозостійкості й корозійної стійкості бетонів, зменшення водопотреби, поліпшення легкоукладальності та зниження витрати цементу.

Ключові слова: композитний плавучий док; залізобетонний понтон; конструювання доків.

Аннотация. Приведены исследования на основе использования критериев выбора оптимальной конструкции и учета действующих нормативных требований, которые дают возможность разработать рекомендации по конструированию и технологии постройки композитного плавучего дока. Обоснован выбор основных параметров, которые позволяют построить обобщенный критерий для выбора оптимальных конструкций плавучих композитных доков с учетом опыта их строительства и эксплуатации, а также результатов экспериментов в наиболее тяжелых условиях докования. Подано использование системы критериев для контроля массы и прочности конструкций дока и комплекса вопросов технико-экономического характера, надежности и удобства эксплуатации. Предложена конструкция композитного плавучего дока с уменьшенным количеством набора в понтоне, в котором арматура, работающая на местную прочность, устанавливается снаружи в направлении наименьшего пролета, а арматура, которая работает на общую прочность, устанавливается внутри элемента. Описаны особенности установки набора в топ-палубе дока и обосновано отсутствие в бетонных башнях шпангоутов, флоров и бимсов. Поданы конструктивно-технологические схемы конструктивного мидель-шпангоута плавучего дока и стапеля для постройки композитных плавучих доков, использование которых позволяет уменьшить материалоемкость и снизить трудоемкость их постройки. Приведены технологические рекомендации армирования днищевых плит понтона композитного плавучего дока. Представлена схема армирования днищевых плит в районе восприятия максимального гидростатического давления. Показано, что защитный слой бетона для рабочей арматуры обеспечивает совместную работу арматуры с бетоном на всех стадиях работы конструкции, а также защиту от агрессивных внешних воздействий окружающей среды. Приведены особенности выбора судостроительного бетона, ориентированного на экстремальные условия работы морских железобетонных сооружений. Рассмотрено влияние воздуховтягивающих и пластифицирующих добавок в бетонной смеси на улучшение прочности, непроницаемости, морозостойкости и коррозионной стойкости бетонов, уменьшение водопотребности, улучшение удобоукладываемости и снижение расхода цемента.

Ключевые слова: композитный плавучий док; железобетонный понтон; конструирование доков.

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Problem statement. When designing the dock hull as a whole and its individual components and parts, considerable difficulties are stipulated by the complexity of the operation of the structures and the variety of functions performed by the individual hull elements. The desire to design the structure so that each element of it best fulfills its functional purpose during operation and is rational during construction and repair necessitates the harmonization of conflicting requirements with regard to economic indicators. The task of the designer is designing such a hull so that it, at the lowest cost of construction and mass, satisfies the operational requirements as much as possible and is sufficiently reliable throughout the entire service life for it with minimal amounts of periodic repairs and maintenance costs. Thus, the minimum cost of construction and operation is the main generalized economic indicator, objectively takes into account the quality of the design from the standpoint of the interests of the pre-production enterprise.

The problem of increasing the level of design and technology is complicated by the fact that, due to objective and subjective reasons, it is not always paid enough attention at various stages of design, engineering and technological developments. One of the main reasons for this is the lack of necessary criteria for the development of a generalized assessment in the form of any indicator.

Analysis of latest studies and publications. The constant needs of world shipping in ship repair, inspection and monitoring of the state of ships, maintenance of the underwater part of ships cause an increased demand for floating docks. The analysis [11] of the operating conditions of the composite floating docks showed that they are to a large extent extreme. In addition, the specifics of the technology and organization of the construction of large lifting docks requires the solution of a number of technical problems that have no analogues in the world practice. In the floating dock, as well as on the ship, all the requirements of classification and insurance companies for monitoring its condition and restoration of working capacity apply.

Recently, composite so far, made partly from reinforced concrete and partly from metal structures, have been in great demand [3, 7]. As a rule, a pontoon is made from reinforced concrete, and side towers are made entirely from metal.

The main direction to achieve competitive products of dock-building enterprises is the introduction of scientific research aimed at upgrading, improving training, organizing and managing production, reducing construction time, reducing costs and improving product quality, minimizing the use of all types of resources and costs, the use of new technologies [4, 8].

Conclusion of previously unresolved parts of the overall problem. The choice of optimal designs should be based on the obligatory consideration of complex interdependencies of an economic nature in order to find the most optimal solution. This work is very difficult, and it should be carried out simultaneously with the search for theoretical and practical solutions based on the experience of building and operating docks, as well as the results of experiments in the most difficult conditions by docking.

THE AIM OF RESEARCH is development of recommendations for the design and technology for constructing a composite floating dock based on the use of criteria for selecting a rational design and taking into account existing regulatory requirements.

Methods, object and subject of research. When performing the study, the method of coagulation was used, which consists in reducing the multicriteria task to the single-criterion task. For the construction of a multicriteria problem of making optimal decisions, it is necessary to transform a set of specified criteria into one generalized criterion that expresses the usefulness of a given system of criteria. The object of research is the design process and the technology for constructing a floating composite dock. The subject of research is the design of the composite floating dock.

Basic material. To solve the complex problem of designing the structures of the dock hull, it is necessary to have a certain system of criteria that allows for a comparative objective assessment of various options for possible solutions. Such an assessment in the period of intensive progress of science and technology acquires special significance. Previously expedient designs were chosen based on the requirements of the rules of classification societies containing specific recommendations derived from operating experience of previously constructed docks. It was believed that such design provided reliable structures in operation. In modern conditions of implementation of the recommendations contained in the rules, it turns out to be insufficient through the rapid change of quantitative and qualitative characteristics of the docks of the facilities under construction.

However, it is not easy to develop such a system of criteria: it is necessary to take into account a large number of factors whose influence can’t always be established with sufficient certainty. Therefore, at the moment it is possible to simultaneously take into account only a limited number of requirements. Some of the same requirements remain unheeded and are accepted as secondary. As a result of this simplification, the physical essence of the questions is distorted, the reliability of the results obtained may be insufficient, and the approximate criteria obtained in this way can be recommended only as some conditional measures.

Given the above, in this article it is necessary to determine the modern basic criteria that ensure the reliability and optimality of the dock structures.

Errors in the design of reinforced concrete structures can be caused by unsuccessful assembly structures, improper reinforcement, improperly chosen classes and grades of concrete and reinforcement, insufficient stability of structures, disregard for possible corrosion of concrete and lack of instructions on the construction of structures. When designing structures, it is necessary to ensure strength so that the fracture of structural elements is plastic, but not brittle. This is achieved by using plastic steels, observing the minimum and maximum percent of reinforcement [1].

All structures on the docks must be reliable, which leads to the need to create a certain safety margin and the more, the more there can be an error in determining the external forces acting on the dock's hull. This is done in case of a possible excess of the existing forces as compared with the permissible ones in order to take into account the effect of reducing elm thickness from corrosion and abrasion, as well as due to the presence of hidden material defects and deficiencies in the fabrication of structures. The adoption of an excess margin of safety in order to increase the reliability of structures in operation will inevitably increase the mass of structures and the cost of their manufacture. Therefore, determining the appropriate safety margin is a responsible job, especially when consider that the designer, taking a decision, takes responsibility for the lives of the crew of the dock. The purpose of the safety margin should be consistent with the possibilities of improving the technology of manufacturing structures.

The desire to reduce the weight of the hull, that is, to reduce the cost of materials and labor costs, as well as to increase the payload capacity of the dock, is always an important task of the designer, as it allows to obtain a large economic effect, but optimal design involves the joint consideration of minimizing mass and cost other functional parameters (Fig. 1).

Optimization is carried out on the total costs, which include costs associated with an increase in the mass of structures, and costs associated with a decrease in the probability of its destruction. It is assumed that the probability of failure depends on the quality of the material.

An increase in the yield strength of the material, the achievement of which is taken as a dangerous state, makes it possible to reduce the design dimensions of the structures. In the construction, some part of the yield stress is allowed.

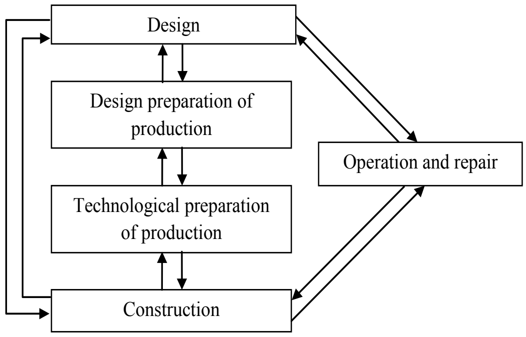


Fig. 1. Scheme for comprehensive consideration of optimal design and technology issues

In recent years, in order to reduce the mass of the dock hull, modern modifications of base materials — concrete and steel are widely used for the manufacture of structures, as a result of which a significant economic effect is achieved, despite their higher cost. When building a dock from ordinary carbon steel, the proportion of metal elements in the total weight of the built dock increases markedly as the size of the docks increases. In order to preserve this proportion of metal elements at the same level as increasing the size of the docks, it is necessary to use reinforced steel of high strength and high-strength concrete when building a pontoon, and when forming the structure of towers to use steel of high strength.

So, entering from the above analysis, it can be argued that reducing the hull mass, that is, reducing the consumption of materials and labor costs due to the use of reinforced steel of increased strength and high-strength concrete when building a pontoon, as well as using increased strength steel when forming the tower structure, increasing the useful dock carrying capacity and cost minimization are one of the main factors ensuring the reliability and optimality of the dock design. But it should be noted that these factors are rather contradictory.

Linking different and contradictory requirements and obtaining a successful solution is a difficult task, since there are no interrelated indicators that meet different requirements. This is especially true of design and construction technology. Considering the fact that in most practical problems, decisions are evaluated according to several qualitatively different criteria (Table 1), then hypothetically one of the solutions may be the best according to all criteria, and it will be the most optimal.

In the case of a complex relationship between modern requirements for structures, minimizing mass from a technical and economic point of view does not always lead to an optimal solution of the problem. Direct proportionality between the mass of structures, the complexity of manufacturing, operational and technical and economic efficiency is not observed.

When considering the reliability and durability of structures, it is necessary to fully consider the technological factors associated with the construction and repair of docks, during which welding stresses and deforma-

Table 1. Relationship between the basic requirements for the dock design and their optimization

Elements of design optimization	Basic requirements								
	Reduction of parts nomenclature	Typing and assembly, automation	Reduction in materials and blanks	Material savings	Reducing the complexity of products	Cycle time reduction	Reducing the cost of pre-production	Reducing work requiring high qualifications	Full capacity utilization and reduced shipments
Normalization, unification, typification	+	+	+	+	+	+	+	+	–
Compliance material blanks final form	–	+	+	+	+	+	–	–	+
Rationality of sizes and configurations	+	+	–	+	+	+	+	+	+
Convenience of processing, assembly, welding and measurements	–	+	–	–	+	+	–	+	–
Accounting for enterprises and their production capabilities	–	+	–	–	+	+	–	–	+
Workability sizes and tolerances	–	+	–	–	+	+	+	+	+

tions occur in hull structures, creating a concentration of stresses in various technological cutouts. Also, as a result of errors in the preparation and execution of technological operations, defective joints are obtained, the mechanical qualities and chemical composition of materials change, a volumetric stress state arises, and so on.

The practice of building and repairing docks using modern advanced methods has developed some well-defined requirements (Fig. 2) in dock structures, more and more unifying and standardizing in order to shorten the cycle time of work, improve quality and reduce manufacturing cost. Therefore, typing of components and parts for docks for various purposes is becoming widespread.

In this regard, in recent times, special importance is attached to the development of industry standards by drawing albums for choosing the shape and size of structures, eliminating the mistakes of designers. At the same time, it is necessary to strive so that the unification and standardization do not hinder the improvement of structures. To do this, it is possible to regularly review the content and recommendations of the standards in order to take into account new research in the field of design. Using the same unification and standardization always gives a great economic effect and ensures high quality of the designed structures, especially if technological issues are taken into account.

The design of new structures should be accompanied by an assessment of individual flaws that appear as a result of making compromise decisions. However, trying to find the optimal solution, sometimes it is necessary to completely distract from the usual constructive methods and try to offer completely new designs, since on the docks built at different times, there are often designs whose shape and size were caused by reasons that have ceased to exist. It is possible to propose the following algorithm for evaluating the design and technology for constructing composite docks (Fig. 3).

Separate constructions, appeared by chance and did not manifest themselves in operation negatively, sometimes they become standard and are recommended by tradition. Some constructions on the same type docks, built in different countries, significantly differ from each other in terms of working conditions, and sometimes even in principle.

At present, as a result of the transition to a scientifically based design of structures using a system of criteria, it became possible to control not only the weight and strength of structures, but a whole range of technical and economic issues, reliability and ease of operation.

The choice of optimal designs should be based on the obligatory consideration of complex interdependencies of an economic nature in order to find the most optimal solution. This work is very difficult, and it should be carried out simultaneously with the search for theoretical and practical solutions based on the experience of building and operating docks, as well as the results of experiments in the most difficult conditions by docking.

One of the most commonly used methods for solving such multi-criteria tasks is reducing a multi-criteria task to a single-criteria one. For the construction of a multicriteria problem of making optimal decisions, it is necessary to transform a set of specified criteria into one generalized criterion, which expresses the usefulness of a given system of criteria. The main difficulty in solving this problem is the need to compare criteria of a different nature and determined in different scales. If this complexity is solved and all output criteria W_i $(i = 1, 2, ..., k)$ expressed in comparable units, then the generalized criterion is represented as a weighted sum of individual performance criteria [10]:

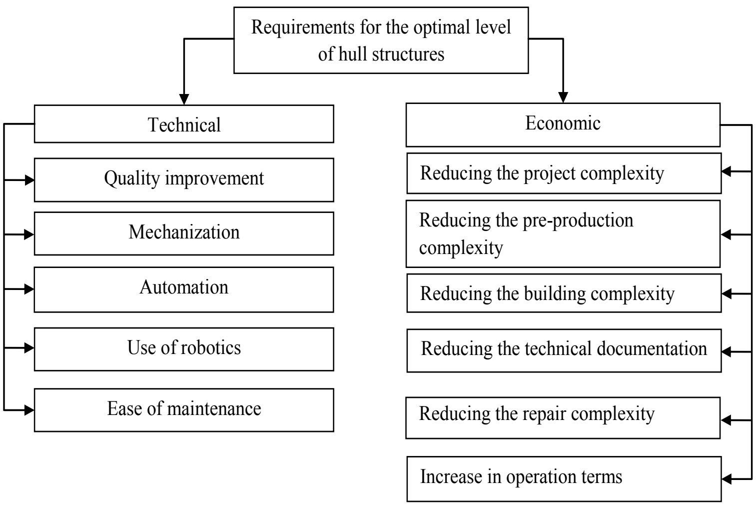


Fig. 2. Requirements to ensure the optimal level of hull structures

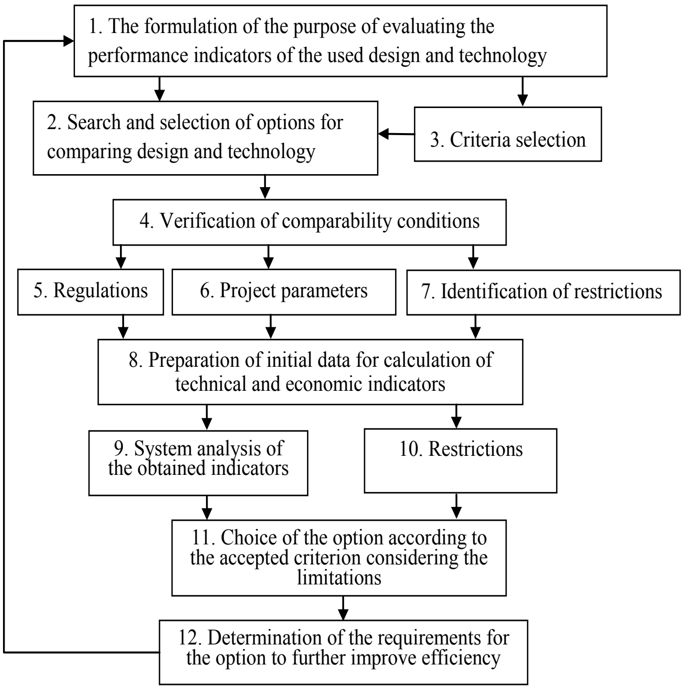


Fig. 3. Algorithm for evaluating the performance indicators of the design and construction technology of composite docks

$$U = \sum_{i=1}^{k} a_i \cdot W_i,$$

where a_i — weights with “+” sign under the conditions that it is desirable to increase, and “–” sign with those that it is desirable to reduce.

A common disadvantage of the component criteria is that the lack of effectiveness in one of them can always be compensated at the expense of the other. Therefore, their use may lead to incorrect recommendations.

Of the many indicators of efficiency, they single out one, the most important, and seek to obtain the optimal solution only by this single criterion. On other performance indicators impose restrictions of the form [10]:

$$W_i \geq w_i, (i = 2, \ldots, m); W_j \leq w_j, (j = m + 1, \ldots, k)$$

and include in the number of specified conditions. Performance indicators are in order of decreasing importance. For simplicity, let’s assume that each of them needs to be turned into a maximum (if this is not the case, it is enough to change the sign of the indicator). First, a solution is sought, which turns the W_1 indicator to a maximum. Then, based on practical considerations and the accuracy of the source data, some assignment ΔW_1, at the cost of which it is possible to achieve the maximum of the indicator W_2, that is, the restriction $W_1 \geq W_1^* - \Delta W_1$, where W_1^* – the maximum possible value of W_1, is imposed, and this limitation, we are looking for a solution in which the maximum of the indicator W_2 is reached. This process continues as needed. This method of finding a compromise solution is good because it is always known, at the price of which the assignment in one indicator gains in the other.

From a formal point of view, the construction of a generalized criterion is a procedure for aggregating particular criteria into one criterion. The main requirement, the fulfillment of which is necessary, is maintaining the dominance relation for the generalized criterion. This means that [10]:

$$(W_1, W_2, \ldots, W_m)^{Par} > (U_1, U_2, \ldots, U_m) \Rightarrow$$
$$\Rightarrow F(W_1, W_2, \ldots, W_m)^{Par} > F(U_1, U_2, \ldots, U_m),$$

where F — the aggregate-operator of the generalized criterion. Considering the generalized criterion as a function of m variables (partial criteria), let’s define the level surface for it:

$$F(W_1, W_2, \ldots, W_m) = c.$$

For any values of partial criteria corresponding to this equation, the generalized criterion does not change its value equal to c. Using this circumstance, it is possible to change the value of particular criteria, keeping the value of the generalized criterion unchanged. When a measure of the effectiveness of criteria expressed in heterogeneous units, for example, monetary and temporary, they must be reduced to a standard measure of efficiency or transformed into dimensionless ones.

Using one of the above solutions to multicriteria problems, one can construct a generalized criterion for choosing the optimal dock structures.

Fundamentals of design and construction technology of composite docks

Design, construction and building of composite floating docks is carried out in accordance with the rules of the Shipping Register of Ukraine [9], ABS [12], "Rules for building hulls of ships and floating structures using reinforced concrete" [6] and under the Register's technical supervision.

In accordance with the requirements of the Register, the construction and use of composite floating docks should be carried out on the basis of the technical and economic feasibility of their use in specific conditions, taking into account the maximum reduction of material intensity, energy intensity, labor intensity and cost.

The rules [6] establish the basic requirements for materials, construction, strength and technology for constructing a dock hull, manufactured using reinforced concrete. In this case, when designing the floating docks, design schemes should be adopted that provide the necessary strength, stability and spatial immutability of the structure as a whole, as well as individual structures at all stages of construction and operation. Devices, equipment and software, stability, division into compartments, fire protection, mechanical installations, systems and pipelines, boilers, heat exchangers, electrical equipment, rescue and signaling equipment, radio equipment, lifting devices, must meet all the requirements applicable to them Register rules, state standards and other regulatory documents.

When designing floating docks, Rules [6] recommend the following sequence:

– implementation of the constructive layout of the pontoon and towers;

– determination of design loads causing local and general deformations of hull structures;

– design of dock structures from the condition of ensuring local strength and stability, taking into account the limitations on the minimum thickness;

– design of structures that provide the overall transverse and longitudinal strength of the pontoon;

– design of structural elements of the hull, ensuring its overall longitudinal strength during operation (in dock operations)

– verification calculations of the total and local strength of structures in the conditions of the route from the construction site to the place of dock operation.

Metal towers of composite floating dock, it is advisable to dial on the longitudinal dialing system. In this case, the transverse frame connections (frame beams and frames) of the walls and decks of the towers should be located in the plane of the main cross links of the pontoon. The frame connections of the outer and inner sides of the towers below the safety deck should be interconnected by expansion beams that must be installed in the plane of each main cross-tie of the pontoon.

In modern conditions, to improve the quality characteristics of the pontoon, reinforcement of the concrete of the pontoon is made of fiberglass, which leads to a significant increase in the compressive strength of concrete (120…170 MPa) [14, 20]. With increasing strength, the modulus of elasticity of concrete increases, which improves its operation in conjunction with steel reinforcement [14, 17]. The use of additives helps to improve the quality characteristics of the concrete mix and the effect on the setting and hardening processes. Reinforcing additives have a positive effect on water absorption and increased stability of the resulting concrete given the number of freezing cycles [13, 20], and cracking is also significantly reduced in such concrete [19, 18]. A promising direction in the manufacture of concretes is the use of plasticizers, such concretes are characterized by reduced water absorption [16]. When conducting a comparative analysis of the use of plasticizers based on polycarboxylate ethers of various manufacturers, one of the parameters was compressive strength, which for concrete with the same cement consumption in a solution without additives was 24,5 MPa, and with additives 42,9…43,8 MPa, almost doubled its strength [2].

So, in the case of increasing the mechanical characteristics when using the modified mixture, it is possible to reduce the thickness of the concrete base or reduce the number of reinforcing elements. The expected positive effect, in addition to the overall material savings, is a reduced mass of the structure, an increase in the carrying capacity, the possibility of minimizing the depth of the submerged part of the pontoon and a reduction in labor costs.

The rules [6] give the definition of materials, structures and distances between them, equipment, etc., which are used in the construction of floating docks and, in addition, regulate the use of concrete and its components for the pontoon of the floating dock. Concrete must have the necessary strength, water resistance, frost resistance, chemical resistance in aggressive aquatic environment, have low water absorption and a protective layer, reliably protects the reinforcement from corrosion. To ensure the necessary reliability and durability of floating dock hulls manufactured using reinforced concrete, it is necessary to use concrete of the corresponding strength classes and grades for water tightness and frost resistance, especially in zones of varying water levels and exposure to ice. To improve the basic properties of concrete (strength, impermeability, frost resistance and corrosion resistance), reduce water demand, improve workability, reduce cement consumption, and perform concrete work at negative ambient temperatures, it is recommended to add special (air entraining and plasticizing) additives to the concrete mix.

Hot-rolled reinforcement bars of the corresponding classes that meet the requirements of classification societies [12] should be used for the reinforcement of hull reinforced concrete structures. Sheet steel for hull structures of composite floating docks should also meet the requirements of classification societies [12].

Part of the hull of composite floating docks is a reinforced concrete pontoon and its elements are composing, consisting of plate structures, supported by ribs or partitions, which form a transverse, longitudinal or mixed system of cross elm. The reinforcement of the hull elements should be carried out by bar reinforcement in the form of welded reinforcing grids and frameworks. Connections of reinforcing bars between themselves and with parts must be welded.

Parts of the reinforced concrete hull, which during operation are subjected to shocks and invasions, should be strengthened or protected by the freeboard bars, which have sufficient strength, durability and reliability under the influence of these loads and ensure the transfer of forces to rigid bindings of the hull. The protective layer of concrete for working reinforcement should ensure its joint work with concrete at all stages of the structure's operation, as well as protection from aggressive external environmental influences. The thickness of the protective layer of concrete for rod reinforcement of the external surfaces of reinforced concrete hull elements must be at least 15 mm, for the dock-floor — at least 20 mm, for internal wetted hull elements — at least 10 mm, and for internal hull elements, not exposed to aggressive factors — not less than 5 mm.

The fastening of the foundations of mechanisms, equipment, ship devices and other elements of saturation in reinforced concrete hull structures should be carried out by welding to embedded parts or anchor bolts.

When constructing reinforced concrete structures, their dimensions should be assigned from the condition of ensuring sufficient strength and reliability of both the elements themselves and the joints. Steel partitions, frames, beams of the set and other elements of metal structures should be located in the same plane with the corresponding reinforced concrete elements. Steel elements of composite structures should be joined to reinforced concrete with the help of special embedded parts or anchors capable of transferring reinforced concrete to all the efforts acting in a joint. Steel towers of composite docks should be welded with solid double-sided butt seam or at an angle to solid embedded parts installed in the reinforced concrete pontoon hull.

The main methods for constructing a reinforced concrete part of a composite floating dock are an assembly one, in which the pontoon consists of prefabricated flat sections, and a block one when it consists of three-dimensional blocks, each of which consists of flat sections. Requirements for the manufacture and installation of reinforced concrete hull structures must comply with the Rules for the construction of hulls of ships and floating structures with the use of reinforced concrete [6]. The manufacturing techniques of the elements of metal hull structures, as well as the metal parts of the towers of the composite floating dock should be similar to the manufacturing techniques of the steel ship structures. It is allowed to splice the hull parts afloat from separately constructed floating blocks, provided that the adopted design and technology for connecting the blocks into a single whole ensure the strength and water resistance of the monolithic hull.

The hull of the composite dock consists of a reinforced concrete pontoon (bottom, outer skin, inner longitudinal and transverse structures) and two steel towers (outer and inner skin, decks, platforms, partitions and supports of their set). During the operation of the dock, its hull is affected by the mass of the dock itself, the support forces, the ballast weight, the ship’s pressure, winding, wind load, and during the sea crossing the dock receives additional forces from bending and torsion, wave shock loads. When calculating the main bindings, perceiving the load from the ship, it is considered that the external forces acting on the dock-ship system are perceived by the dock hull and the ship. The total bending moment on the dock ship system midship is distributed between the dock hull and the ship in proportion to their strength. Therefore, for the calculated bending moment take the smaller of the moments that may occur during operation. When docking the ship, a part of the bending moment can be reduced by taking ballast. The amount of bending within acceptable limits usually contains the reception of ballast water.

The slipway for the construction of reinforced concrete ships contains supporting keel blocks that are installed on the supporting surface (Fig. 4, *a*). Metal rigid frame shields associated with keel blocks with hinges and stops (Fig. 4, *b*). A cushion is installed on the top of each keel block (Fig. 4, *c*) [5]. Omitted boards alternately rise to a horizontal position and fixed stops. Then cushions are fitted and installed, between which one should not allow the formation of gaps into which cement “milk” could get when concreting the bottom plate.

The markup on the slipway is applied once and on subsequent tabs only refreshed in separate places. Reinforcement grids are installed and the bottom plate is concreted. Demoulding begins from the row, which is located on the edge, by cleaning the stop and squeezing the shield using screw tappets. The shield comes off the plate and rotates around the hinge, hanging on it. The whole structure of the ship hull under construction remains lying on the cushion for the construction of reinforced concrete ships.

The above device allows to reduce the complexity of installing the formwork bottom and further demoulding, and also allows to ease working conditions, reduce transport operations for the transport of large-size boards with significant material savings, due to the fact that for the formwork used inventory metal shields that do not require repair after demoulding (i.e. reuse of shields is possible). Due to the fact that the frame shields are attached to the supporting keel blocks with hinges and stops, the exact installation of the formwork in the working position and its demoulding with the lowest cost of manual hard work is ensured.

In the construction of a composite dock with a reduced number of sets in the pontoon of the dock, the reinforcement working for local strength is installed externally in the direction of the smallest span, and the reinforcement operates for general strength and is installed inside the pontoon structural element. The transverse partitions between the inner boards are installed through 4 slats, that is, 3 meters, and in the concrete towers frames, floras and beams are not installed.

When the ship is docked, keel blocks are placed on the longitudinal baffle of the dock, the load from which is transferred to the rarely spaced transverse baffle of the dock, thereby ensuring overall transverse strength.

The construction of concrete floors takes several times more moment of resistance than steel structures, which allows to increase the overlap girder and less often place the partition supports. As a result, the costs associated with the cost of materials are reduced, as well as the labor intensity of the work during the construction of the dock.

The cross section of reinforced concrete slab of dock floors 140 mm thick and the maximum plan size of 6,700×3,000 with reinforcement from 12 to 20 mm in diameter is shown in Fig. 5,*a*. Fig. 5,*b* is a diagram of the reinforcement of bottom plates with a thickness of 160 mm in the region of the perception of maximum hydrostatic pressure.

Reinforced concrete pontoon of composite dock is recruited by the transverse system, and metal towers – along the longitudinal. The dock pontoon is divided by longitudinal watertight baffles into several independent compartments, which are needed to provide the necessary stability when ascending or diving without a roll and the number of which depends on the dock carrying capacity.

They are the main links that absorb the load from the central and side keel tracks. The central keel track is placed above the diametrical partition. Waterproof transverse partitions set at a distance of 4.5 m from each other. Transverse frames of towers are a continuation of the

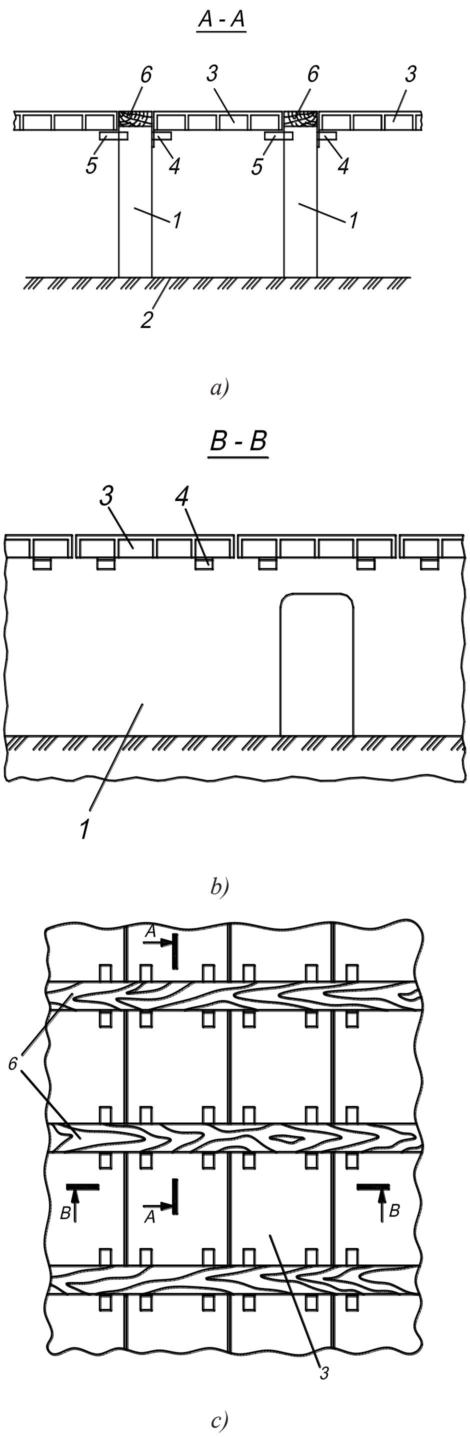


Fig. 4. The site of the slipway:
a — section *A–A*; *b* — section *B–B*; *c* — top view;
1 — supporting keel blocks; *2* — supporting surface; *3* — frame shields; *4* — hinges; *5* — stops; *6* — cushion

transverse set of pontoons. In the limbs of the pontoon to increase the dock floor operation length, which is usually 0.8...0.9 the ship length, establish platforms (crinolines) with wooden or metal flooring.

The safety deck and top deck provide overall and local hull strength. The top deck framework consists of beams that are a continuation of the board framework. Flooring of top-decks in the area of the engine room and the main sump pumps perform removable, which allows to unload equipment for repair. The safety deck separates the ballast compartments from the living and office spaces. It is supported by beams that connect with the onboard transverse set. The water level in the tower ballast compartments and, accordingly, the depth of the dock floor under the water, which is limited by the height of the air pipes placed below the safety deck. The drawings of the constructive midship of the floating composite dock are shown in Fig. 6.

When designing metal dock towers, the effect of corrosion damage on the thickness of structural elements is taken into account. This instruction is based on the rationing of strength until the end of the service life of the dock, which for composite docks is assumed to be 50...60 years. Corrosion additives guarantee the dock operation during the entire specified service life at an average rate of corrosion damage to structural elements.

DISCUSSION OF THE OBTAINED RESULTS

Summarizing all the above, it is possible to classify the basic requirements that provide the ability to construct a generalized criterion for the selection of optimal dock structures:

1) design of the dock must retain the original quality for a specified period of operation;

2) mass of the structure with an adequate margin of safety and efficiency during construction and operation should be minimal;

3) structures should be available during repair and maintenance during operation;

4) constructive solutions must comply with the current industry standards, taking into account existing state standards and standard design albums and recommendations for unification;

5) operation quality must ensure sufficient reliability of the structures in extreme conditions of the dock operation;

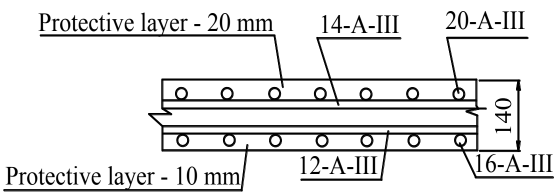
6) technology of manufacture and repair of structures in order to reduce their cost should ensure the following:

– use of the maximum possible size of blocks and sections with full saturation of them on the pre-assembly sites;

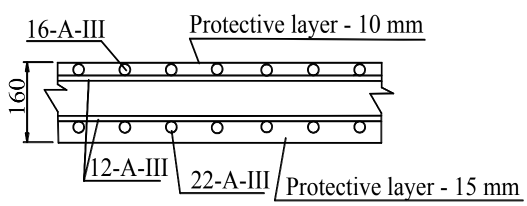
– use of modern progressive technological processes;

– possibility of widespread use of automatic welding and cutting;

– reduction of the amount of work on the preparation in the assembling and welding.



a)



b)

Fig. 5. Scheme of reinforcement of concrete slabs:
a — dock floor; *b* — bottoms

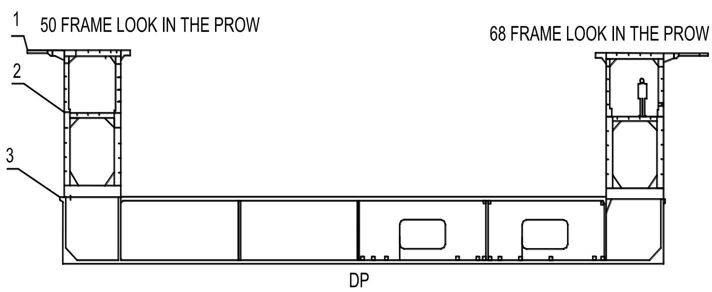


Fig. 6. Constructive midship of a floating composite dock:
1 — top-deck; *2* — safety deck; *3* — dock floor

CONCLUSIONS. The presented studies based on the use of criteria for selecting the optimal design and taking into account existing regulatory requirements make it possible to develop recommendations for improving the design and technology for constructing a composite floating dock. The choice of the main parameters that provide the opportunity to build a generalized criterion for selecting the optimal structures of floating composite docks, taking into account the experience of their construction and operation, as well as the results of experiments in the most difficult conditions by docking, is substantiated. The presented constructive-technological schemes of the constructive midship of the floating dock and the slipway for the construction of composite floating docks, the use of which makes it possible to reduce the consumption of materials and reduce the complexity of the dock construction. The features of the choice of ship-building concrete are given, which is focused on extreme working conditions of marine reinforced concrete structures.

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Статтю рекомендує до друку
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