



Construction of Unique Buildings and Structures



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Sheet pilings from ultra composite in hydraulic engineering

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ABSTRACT

The article presents a comparative analysis of metallic and composite sheet piling with a review of their technical characteristics. Two similar design scheme of the shore protection reconstruction with usage of different materials were considered. Constructive scheme is the erection of a new sheet pile wall and capping beam in dimensions of existing constructions adjacent areas. In the first case, an option for the construction of new metal sheet pile wall with concrete cap beam was considered, in the second – a version of the use of modern domestic composite sheet piling ShK-150. Application possibility of modern ultra composite materials, received with the use of the pultrusion technologies is justified in this work. Application of the results of current justification of the use of composite materials will develop the methodology for applying composite material in hydraulic engineering construction.

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Introduction

Corrosion of metal is one of the main reasons for the decrease in the reliability and safety of structures at marine and river berths [1-13]. Fight against its influence has primary value and can be considered as the independent task and the main source of saving resources. This means that you need to maintain the already constructed buildings, using modern methods of protection and, moreover, the construction of new structures using modern materials – a little corrosive or not subject to corrosion [14-18].

In actual use moorings are exposed not only to the different loads (static, dynamic, cyclic) and temperatures, but also aggressive environments. Besides, in case of the long use of constructions, the aging processes leading to the considerable change of mechanical properties of steel are activated. Frequently these factors may act together and in various combinations, significantly reducing the load carrying capacity and reducing the durability and safety of berths [1, 19, 20].

Causes of corrosion damage of metal in the construction of berthing facilities include [20, 21]:

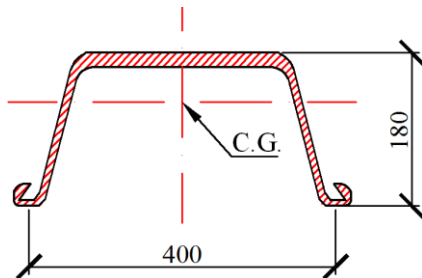
- violation of the rules of production of works for the protection against corrosion;
- excessive long periods between manufacture and implementation of full protection after installation;
- non-compliance with the modes of operation of electrochemical protection systems;
- untimely recovery of protective coatings during operation of structures.

Metal sheet piling

In case of manufacture of sea and river moorings different alloys are applied, for the sheet piling and anchor rods low-alloy steel is most often used. The sheet piling Larsen 4 according to the characteristics is one of the most high-quality sheet pilings, made in the Russian Federation, and also most often applied in domestic construction practice. Manufacture of sheet piling is carried out at the Nizhniy Tagil metallurgical plant [22].

The sheet piling presents in the form of a long (up to 22 m) and narrow (420 mm) metal profiles trough type. Manufacture of sheet piling is carried out by hot rolling according to TS 14-2-879-89 of steel grade STK.

The main advantage of metal sheet piling Larsen 4 is its high load-carrying capacity and the prevalence of the domestic market. The disadvantages include a high weight and the need for corrosion activities which entails more expensive construction. The cross section of the sheet piling is shown in Fig. 1.



Technical characteristics of the sheet piling Larsen 4 are presented in table 1.

Figure 1. The cross section of the sheet piling Larsen 4

Table 1. Technical characteristics of the sheet piling Larsen 4 [22]

Name	Measurement units	One pile section	1 linear meter of the wall
Technical specification	TS 14-2-879-89		
Cross-sectional area (F)	sm ²	94.2	235.5
The weight of one meter (G)	kg	74.0	185.0
Moment of inertia (J)	sm ⁴	5234	39600
Moment of resistance (W)	sm ³	405	2200
Bending stiffness (EJ)	kN·m ²	–	83160
The calculated resistance of sheet piling (R)	MPa	230	230
The maximum bending moment (M_{max})	kN·m	93	506

Ultra composite sheet piling

At the beginning of 2012 specialists of the Russian company JSC "Pultruded technology", based on the latest high-tech developments and the global composites industry, with the support of the "Skolkovo", developed and patented absolutely new series of sheet piles from the ultra composite material, called ShK-150 [23].

JSC "Pultruded technology" is one of the pioneers in the field of pultrusion glass composites – the industry which now is almost absent in the Russian Federation. Previously widespread use fibreglasses restrained mainly lack of industrial technology, which allows establish production of mass consumption. Creation of the pultrusion solved this problem: an issue glass composite profile of various configurations and sizes with the required accuracy was not only possible, but also economically expedient. Currently pultrusion is one of the fastest growing industries in the production of composite materials industry. The popularity of the technology is caused by its efficiency and high degree of automation. Now composite sheet pilings of ShK-150 are made in the Moscow region according to TS 2247-001-92530792-2012. It should be noted that this material has the necessary documentation to carry out its application: certified for compliance with normative documents; expert opinion on the compliance of the material common sanitary and epidemiological and hygienic requirements; certificate of technical qualification in construction; technical certificate GOSSTROY RF and test report. Sheet piles ShK-150 has several advantages over steel sheet pilings:

- less weight of the material;
- corrosion resistance;
- durability;
- lower cost (average market price of the sheet piling ShK-150 is approximately twice less than the cost of the metal sheet piling Larsen 4).

Composite sheet piling is created on the basis of polyester and composite resins, so that it has a carrying capacity that exceeds metallic analogs and the more PVC sheet pilings, which with all its advantages have low bearing capacity.

From the point of view of the geological situation, ultra composite sheet pilings can be used in non-cohesive soils: consisting primarily of gravel, sand, sandy silt, as well as in cohesive: dense soil, consisting of clay and silt. At the end of the construction work we can see strong and reliable construction – an impressive ultra composite wall.

The sheet piling, which is made from ultra composite material has a high mechanical resistance to abrasion, cracking and scratching. It isn't subject to corrosion, rotting and influence of sea water and it doesn't require maintenance. It is flameproof, steady against seasonal difference of temperatures (bearing capacity of a wall makes 200 kNm/lm in case of temperature condition from minus 60°C to plus 50°C without causing permanent deformations). The ability of ultra composite material to withstand corrosive environments is significantly higher than that of steel and concrete. Warranty lifetime piles of this material are not limited.

Connections of the sheet piling take place on the side edge that protects the joint from the main loads experienced by the structure, as the area of the main load falls on the central part of pile section.

Technology of composite sheet pile-driving is quite simple and does not differ from working with steel sheet pilings. Piling of sheet piling ShK-150 can be carried out with the help of the vibratory pile driver, copra, as well as

at a shallow depth of immersion, with the help of an excavator bucket, by forcing into the ground. You can also perform piling of sheet piling with specialized boats or pontoons.

Technical specifications of the composite sheet piling ShK-150 are presented in Tab. 2. Cross-section of the sheet piling ShK-150 is shown in Fig. 2.

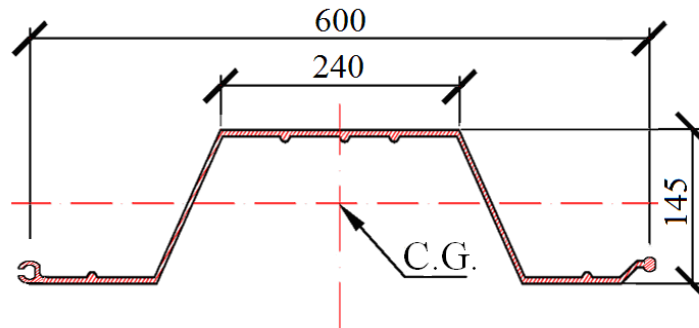


Figure 2. Cross-section of the composite sheet piling ShK-150

Table 2. Technical specifications of the sheet piling ShK-150 [24]

Name	Measurement units	One pile section	1 linear meter of the wall
Technical specification	TS 2247-001-92530792-2012		
Cross-sectional area (F)	sm ²	48.3	84.5
The weight of one meter (G)	kg	10.4	17.3
Moment of inertia (J)	sm ⁴	1684.1	2660.2
Moment of resistance (W)	sm ³	210.67	332.6
Bending stiffness (EJ)	kN·m ²	4378.7	6919.6
The maximum bending moment (M_{\max})	kN·m	237.1	374.5

According to information provided by the manufacturer, to the present time composite sheet piling ShK-150 was used in a number of capital construction and reconstruction on the territory of the Russian Federation and CIS countries. As an example of the object, construction of a pier for mooring large motor yachts in Baku on the Caspian Sea are mentioned [24]. Length facilities – 800.0 m; driving depth – from 4.0 to 13.5 m; soil – sand / clay / shell rock; installation method – vibratory pile driver.

Results and discussion

In this work within the project of repair of bank protection in the form of anchored bulwark with an adjacent slope was estimated comparison of two options with the same design concept, but different range of materials. Constructive scheme implies the construction of a new sheet pile wall in front of the cordon line reconstructed section of coast protection, nodding to the construction of capping beam as construction type and in marks of an adjacent section (figure 3).

The first option involves the construction of shore protection reconstruction sheet pile wall of a metal sheet piling Larsen 4, the second – sheet pile wall from the composite sheet piling ShK-150.

Static analysis and calculation of stability on the circular cylindrical surfaces (CCS) are made to determine the minimum driving of the sheet piles for the two design concepts of the bulwark, which is not anchored.

The calculation is made in the CAD software package – "Hydraulic Engineering", developed by JSC "Lenmorniiproekt." The program complex has a certificate of conformity № ROSS RU. SP15.N00016.

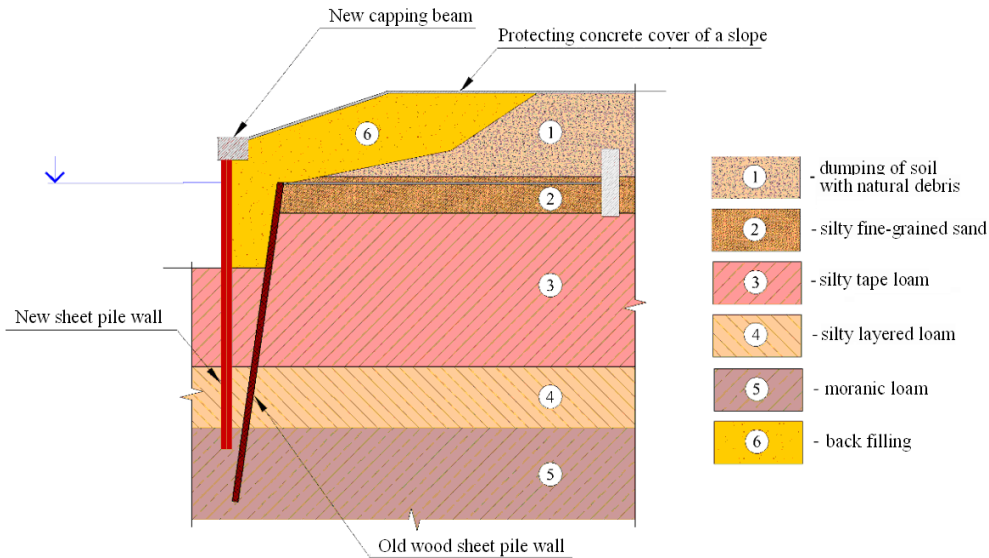


Figure 3. Constructive scheme of reconstructed site of bank protection

During the work in this program complex of two computational modules were used:

- the calculation module for CCS algorithm, which is built on the following guiding and reference documentation [25, 26];

Module static analysis algorithm, which is built on the following guiding and reference documentation [27-29].

It is necessary to notice that the CAD software package – "Hydraulic Engineering" by the production of static analysis, unlike calculation of stability according to the CCS can not take into account the slope of the construction, that is why this part of the structure has been defined as equivalent to the load acting on the horizontal plane passing through the mark of the top of the cap piece at 1 meter length of the structure. Slope was replaced by an equivalent load in both calculations (static stability in the CCS) for uniformity of algorithm of calculation and results.

In conducting static calculations both options have shown good results in strength and stability. Results of the calculations have demonstrated that both types of sheet-pilings can be used for reconstruction of shore protection structures, but for composite sheet piling is required device anchor system, unlike metal, due to lower stiffness indicators. Taking into account the economic feasibility of the technology and production work for the reconstruction of the final version of the device was made of metal sheet piling, as the innovative anchoring system requires the dismantling of existing anchors that complicate the process of the construction work and will lead to significant financial losses.

Despite this, the work demonstrates the possibility of the use of modern ultra composite materials obtained with the use of pultrusion technologies in hydraulic engineering. Application of the results of current justification of the use of composite materials will develop the methodology for applying composite materials in hydraulic engineering. This sheet piling in comparison with the metal has many advantages such as lower cost (double superiority), less weight, good performance on the load-bearing capacity (comparable to metal analogs). Besides that, there is no difference in work between composite and metal sheet piling (the standard set of the equipment is required).

Resume

It is worth mentioning that the development of modern technologies in the production of building materials will help to solve many problems and first of all to reduce construction cost [30-34]. In Russia there are many structures similar to those considered in this work, in which according to the authors, it is possible to use composite sheet pilings. The Russian construction industry has to be changed significantly in the active expansion of composite materials application to the development of their use methods in hydrotechnical objects [35].

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Шпунты из ультракомпозитных материалов в гидротехническом строительстве

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АННОТАЦИЯ

В статье представлен сравнительный анализ металлических и композитных шпунтов с обзором их технических характеристик.

Рассмотрены два одинаковых по конструктивной схеме, но различных по составу материалов способа реконструкции участка берегоукрепления. Конструктивная схема представляет собой возведение новой шпунтовой стенки и шапочногo бруса в габаритах прилегающих участков существующего сооружения. В первом случае рассматривался вариант возведения новой металлической шпунтовой стенки с бетонным шапочным брусом, во втором – рассматривался вариант применения современного отечественного композитного шпунта ШК–150.

В работе обосновывается возможность применения современных ультракомпозитных материалов, полученных с использованием пултрузионных технологий, в гидротехническом строительстве. Применение результатов, относящихся к расчетному обоснованию использования композитных материалов, позволит развить в дальнейшем методологию применения композита в гидротехническом строительстве.

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