Algorithm for estimating loads of supports of floating platforms for extraction and processing of peat raw materials

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Abstract. The optimization of peat production makes it a priority to re-equip the peat industry with new and modernized equipment based on energy efficiency and energy conservation. One could construct more and more new stations and increase energy production by exhausting resources, but one could come up with fundamentally new technologies and energy systems through the accumulation of energy in advanced energy-dense materials and related systems. In other words, it is more reasonable to replace today’s end user with much more budget-friendly and safer energy systems. The systems, as such, should be reliable and easily repairable.

1. Introduction
An alternative solution may be an autonomous floating platform for the extraction and processing of peat raw materials from non-drained deposits. However, the problem of such facilities is a significant size of a floating base composed of articulated pontoons. In this case, the guides to move the platform supports against the surface of the pontoons are linear sliding bearings, the operating conditions of which are very stringent [1–3].

The supporting nodes assume the entire load from the equipment placed on the platform and the extracted peat raw materials. In this case, a statically indeterminate problem is the assessment of forces in the supports during their functioning. In order to ensure the operability of mobile and fixed supports, it is required to identify their workload [4–7].

Figure 1. Scheme of a platform 1 – angle guide; 2 – laydeck underframe; 3 – inner upright; 4 – outer upright; 5 – device for installing and removing piles; 6 – pile anchors; 7 – seat; 8 – linear guide; 9 – joint in the form of half-couplings with power elements in the form of linear motors
2. Materials and methods

One of the options for determining the workload is a theoretical assessment of the forces in the platform supports when solving a statically indeterminate problem. To determine the behavior of a platform under the influence of an external load, a diagram is presented in Fig. 2.

![Figure 2](image1)

**Figure 2.** Frame layout and overall force

Next, we select a certain series and consider the forces in the supports with a statically indeterminate loading scheme. Notionally, we leave only 2 supports, successively moving from one pontoon to another. We derive moment equations in the point $R_{P1}$ (Fig. 3).

![Figure 3](image2)

**Figure 3.** Frame conventional workload
In order to determine the forces in the supports subject to statically indeterminate loading, we notionally leave only 2 supports (support A and support E), sequentially moving from one pontoon to another. We derive force equations taking into account the reaction in the supports and moment equations in point A.

\[ YR_A + YR_{E(DCB)} = P \]
\[ YR_{E(DCB)}l_{E(DCB)} = lpP \]

where \( YR_{(ABCDE)} \) is a reaction force in the support; \( P \) is the total load in the frame; \( l_E \) is a distance between the reaction forces of the supports; \( l_p \) is an arm from the reaction force of the support A to the point of the load P;

We solve jointly the system of equations (1), sequentially determining the conventional reactions in the supports. As a result of calculations upon the expression (2), we obtain the values of the conditioned reactions.

\[
\begin{align*}
YR_E &= \frac{lpP}{l_E} \\
YR_D &= \frac{lpP}{l_D} \\
YR_C &= \frac{lpP}{l_C} \\
YR_B &= \frac{lpP}{l_B}
\end{align*}
\]

To define the influence coefficients, we add the conditional values (according to the above four schemes Fig. 3.)

\[ YR_{A1} + YR_{A2} + YR_{A3} + YR_{A4} + YR_{B} + YR_{D} + YR_{E} = 4P \]  

using (2) we replace the corresponding quantities in (3):

\[
\begin{align*}
YR_{A1} &= f(P) \\
YR_{A2} &= f(P) \\
YR_{A3} &= f(P) \\
YR_{A4} &= f(P) \\
YR_E &= f(P) \\
YR_D &= f(P) \\
YR_C &= f(P) \\
YR_B &= f(P)
\end{align*}
\]

\[ K_E = \frac{YR_E}{4P}, \quad K_D = \frac{YR_D}{4P}, \quad K_C = \frac{YR_C}{4P}, \quad K_B = \frac{YR_B}{4P}, \quad K_A = \frac{\Sigma YR_A}{4P} \]

Another solution to this problem is to assess the loads as with a pile foundation. This calculation is performed against the bearing capacity of the base of a single pile and has the form:

\[ N \leq \frac{F_d}{\gamma_k} \]

where \( N \) is a design load transferred from the structure to a single support; \( F_d \) is bearing capacity of a support; \( \gamma_k \) is a reliability coefficient assigned depending on the method for determining the bearing capacity of a support.

In this case, an assessment of the main and special combinations of loads is performed. The main combinations of loads include constant (dead load of platform parts, weight and pressure on the surface of a pontoon) [8, 9, 10, 11].

The load estimation algorithm is as follows:
1. Identification of the design features of the platform and determination of ultimate strains.
2. Determination of the loads applied to a single support of the pontoon.
3. Assignment of the section sizes and support lengths.
4. Assignment of the design scheme of the support, which determines its bearing capacity.
5. Determination of the number of supports and rows, as well as the distance between the supports on the platform.
6. Definition of the loads transferred to the supports, taking into account the weight of the frame and laydeck of the platform.

The mass of a running meter of a frame 1 m wide, 0.25 m high, made of a 60x40x5 mm pipe will be 61 kg. The mass of a support 1.5 m high, made of 0.2 m pipe with a wall thickness of 8 mm will be 60 kg. To calculate the total number of supports, you need to divide 30 m (frame length) by 1.5 m (support pitch) and add 1 pc. If necessary, the value is rounded to the nearest integer downward. We get 21 pcs. Then the mass of the whole structure as the sum of the masses of the laydeck, supports and frames will be 3.3 tons. Taking into account the load from the equipment and the extracted material, we take a total load of 21 tons. Then the load per one support will be 10kN.

3. Schematic solutions of the platform
Guides for supports should have the following properties, namely: to ensure the movement of nodes with minimal deviations from a given trajectory with an exact return to a specified position; to create the least resistance to the nodes moving; to preserve the efficiency and accuracy over a long period of operation; to reduce and, if possible, eliminate uneven movements and jumps during a low-speed traverse and when a facility starts and stops; to provide damping of vibrations resulting from a low-speed traverse.

Dovetail slides are convenient in that four glide planes are enough to bear loads in all directions, including tipping points. However, these slides are difficult to manufacture, have insufficient rigidity and are usually used for low speeds and average accuracy requirements.

The main criterion for the performance of the guides is their wear resistance. The wear resistance of the guides is influenced by many different factors, the main of which are the material and heat treatment of the guides, the pressure and its distribution along the faces and length of the guides, working conditions (lubrication, pollution, etc.), and the nature of the displacement. These guides usually work at small and medium sliding speeds (up to 1.5 m/s) with small specific loads of up to 1 MPa.

The linear displacement unit is called a linear sliding bearing as there is sliding friction between its mobile and fixed parts. One of the parts of the sliding guide is a rail that is attached to the supporting frame, while its second part – a carriage or the second rail – to the support that should be set in motion.

There are many types of sliding guideways that vary in design, original materials, and purpose. Sliding guides include linear bushings on a cylindrical or splined shaft, profile rail guides with a rail and a carriage, precision sliding guides with two rails and a V-shaped section of the contact area. Steel or aluminum are used as the original materials. Lubrication-free friction pairs are steel/PTFE, steel/polyamide, steel/polyoxymethylene. Friction pairs requiring lubrication are steel/bronze, steel/steel. Lubricants are oil, grease, solid lubricant (graphite, molybdenum disulfide).

The life of sliding guides depends mainly on the load, sliding speed, temperature and duration of use. Additional limiting factors include contamination and corrosion, for serviced options operating without lubrication or running out of it.

4. Conclusion
The paper presents a methodology for the assessment of the forces in the supports during their operation, which enables to take into account the redistribution of loads between the supports. Analytical expressions are obtained for determining the bearing capacity of supports for horizontal and moment loads depending on the length of the supports, bending stiffness, and the strength parameters of a pontoon. The linear interrelation between the bearing capacity of the support and the horizontal and moment load is established.

The proposed algorithm enables to achieve an accurate result of the loads on the platform in order to avoid the loss of stability or breaking joints of the pontoon base. The proposed calculation methodology
complements the more rational use of platform strength resources and is recommended for use in the design of this structure and maintaining operational properties.

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