RESEARCH AND CALCULATION OF METHOD TO ASSEMBLE SMALL PLASTIC FLOATING PONTOONS MAKING FLOATING WORKING FLOOR DURING UNDERWATER DRILLING

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Abstract

The present article proposes the calculation of a floating working platform assembled from small plastic floating pontoons used in drilling underwater borehole. The author uses self-programmed software by the Visual Basic language to check the buoyancy, the stability of the platform. Result of the survey shows optimal option of floating working platform to apply in practice. The author draws conclusions for the selected option of platform to build a scientific basis to determine the possibility of using plastic floating pontoon to make floating platforms used for the drilling underwater borehole.

Keywords: *Plastic floating pontoon; floating working floor; buoyancy; stability; drilling underwater borehole.*

1. Introduction

In the underwater blasting work, the drilling is often performed on a special floating platform named special floating platform. However, it is likely hard to apply those special machines in Vietnam with small-scale blasting account for majority, low water depth (< 3m), mild waves (not excessive grade 1), drilling equipment has a small load due to cost and performance. It is clear to study an appropriate structure apply in those situations. To solve this matter, in this article, author introduces a suitable one which is made up of assembling plastic floating pontoons.

2. Scientific foundation of the plan proposed

2.1. Overview of the work platform assembled from plastic floating pontoons

Plastic floating pontoons unit is made of plastic with very high molecular weight to resist aging under the influence of sunlight and seawater [8]. The unit size is 500 x 500 x 430 mm (length x width x height), with a volume of 6.4 kg, plastic material HMW HDPE (Figure 1a). The plastic float is designed in a modular form, can be firmly connected to each other, so it has overwhelming advantages such as easy transportation, easy installation, short installation time, low cost, large buoyancy, easy to change the shape of the structure, simple installation, high durability, safety ...

From these plastic buoys can be fabricated into floating platforms used in drilling

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holes underwater by putting these buoys together (Fig. 1b). This type of working floor ensures some of the following requirements:

Fig. 1a. Pontoon unit

Fig. 1b. Plastic floating platform

- Enough space to install drilling machine and other equipment, also make sure sufficient area to operators easily perform. There is a small hole that the drilling machine can drill through it. This is a special requirement for this platform in order to drill the borehole.

- Ensure the necessary buoyancy. The lift force of the floating material used must be greater than the total weigh of the platform and the equiments.

- Ensures stability during its operation.

2.2. Options to install drilling equipment on working platform

Based on the requirement to use the working floor where drilling equipment is installed, the following proposals are proposed:

2.2.1. Option 1: The drill is fixed on the floor

The drilling machine is fixed at the center of symmetry of the floor, drilling through the available hole. After drilling the curent borehole, both the platform and the drill machine move together to new position. This is the simplest diagram. The benefit is that the area of the platform can be minimized, saving materials. The drawback is that it spends longer time to operate beacause of movement. The scheme's principle is shown in Fig. 2.

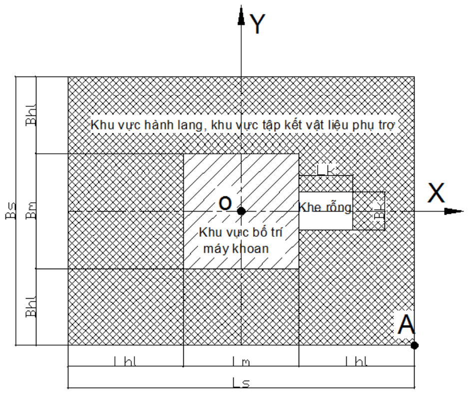

Fig. 2. Floating working platform with a fixed drilling machine according to option 1

The floor size L_s x B_s x H_s (length x width x height) (m) is assembled from the linked plastic pontoon to form a float system. There is a small hole with the size L_k x B_k (length x width) (m), ensuring enough space for the drill throughout and not to impact the body of the platform. It is convenient to manipulate in the extreme situation especially the influence of horizontal displacement. The width of the corridor horizontally, B_{hl}, vertically H_{hl} ensures the smooth movement of the crew of the drill operators. The size of the drilling area is B_m x L_m (m) depending on the type of drill machine.

According to the manufacturer's announcement [8], the plastic pontoon surface has been specially designed to withstand the force. However, to ensure the surface without damage, the platform is covered by a wooden board layer with a thickness of t_{lp}.

2.2.2. Option 2: Portable drilling machine on the working floor

The platform dimensions are the same as option 1. The difference is that the drill machine can be moved on the working floor. Thereby, the drill can be arranged on a slide or track, or a rack with wheels [7]. The operating area of the drilling machine is B_mxL_m (m) in size, arranged near the center to limit the eccentric load. The platform consists of 2 line gaps along the length of the floor. The drill moves along the gap to drill. The number of drill bits along a gap depends on the length B_k of the gap and the designed borehole distance. In this case, the drill machine will be located eccentrically from the center O of the floor with the distance e_x and e_y. The advantage of this option is that it is possible to increase the drilling speed, shorten the performance time due to less displacement. The disadvantage is that the platform area must be larger and consume more material than option 1. The principle diagram of this working floor option is shown in the following Fig. 3.

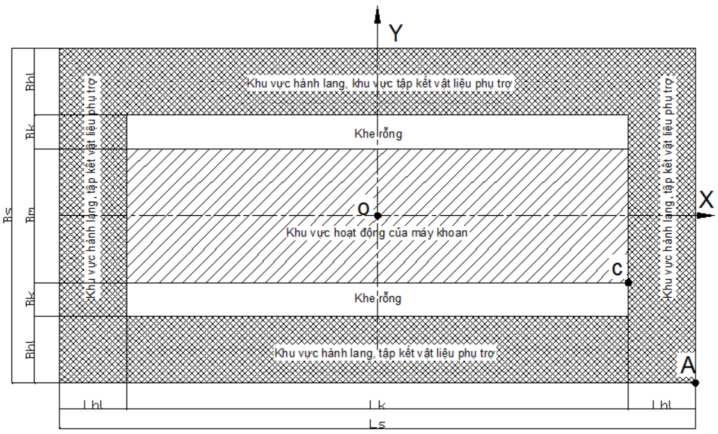

Fig. 3. Floating working platform with 2 gaps for portable drilling machine according to option 2

2.3. Determination of minimum length and width of the working platform

The working floor must have a sufficient area to arrange the drilling machine, auxiliary equipment and space for operators to operate.

For the permanent drill option, the size of the drill site depends on the type of drill used, usually taken as $B_m^{\min} = 2.0\,\text{m}$, $L_m^{\min} = 2.5\,\text{m}$ for common small capacity drills. The hallway width is $B_{hl}^{\min} = 1.0\,\text{m}$, $L_{hl}^{\min} = 1.0\,\text{m}$, ensure smooth operator movement. Thus, the minimum width of the working floor is: $B_s^{\min} = B_m^{\min} + 2 \cdot B_{hl}^{\min} = 2.0 + 2\times 1 = 4\,\text{m}$, and the minimum length of the working floor is: $H_s^{\min} = L_m^{\min} + 2 \cdot L_{hl}^{\min} = 2.5 + 2\times 1 = 4.5\,\text{m}$.

For the option of portable drilling machine on the floor, the number of empty slots is usually 2, with the width of each hollow slot is $B_k^{\min} = 0.5\,\text{m}$ equal to the size of the width of a plastic float, the length of the empty slot $L_k^{\min} = 4\,\text{m}$ to ensure that the drill moves 2-3 holes, spaced 1-2m apart; The hallway width is $B_{hl}^{\min} = 1.0\,\text{m}$, $L_{hl}^{\min} = 1.0\,\text{m}$ sufficient to ensure smooth operator movement. The width of the operating area of the drill is $B_m^{\min} = 2.0\,\text{m}$, the length of the active area of the drill is $L_m^{\min} = L_k^{\min} = 4\,\text{m}$. Thus, the minimum width of the working floor is: $B_s^{\min} = B_m^{\min} + 2 \cdot B_k^{\min} + 2 \cdot B_{hl}^{\min} = 2 + 2\times 0.5 + 2\times 1.0 = 5\,\text{m}$, and the minimum length of the working floor is: $L_s^{\min} = L_m^{\min} + 2 \cdot B_{hl}^{\min} = 4 + 2\times 1.0 = 6\,\text{m}$.

3. Survey of the stability of the work platform assembled from plastic floating pontoon

3.1. Assumptions for building calculation model

To build a computational model, it is necessary to have the following assumptions:

Working floor ensures floating condition

According to the theory of buoyancy calculation presented in [2, 3], the draft of the floating platform with weight *G* is canculated as follows:

$$T = \frac{G}{\delta \cdot \gamma \cdot L \cdot B} \tag{1}$$

where δ is the coefficient of full volume. For rectangular buoys, $\delta = 1$. Floating condition are guaranteed when the draft T is less than allowable draft [T]:

$$T \le [T] \tag{2}$$

Working floor ensures stable static condition

For transverse stability, it is common to consider the stability follow two cases of the angle of heel (small ≤ 15º and large >15º).

However, to ensure safety when drilling construction, the author proposes to design floating working floor with small angle of heel. Therefore, the first theory of floating floor stability is applied to this case and can be presented as follows [2, 3]:

Any object floating on the water surface, it will be tilted under a certain torque. When we do not consider to the tilted torque, if the object returns to its original position, we say that the object is stable. Assume that the floating object is subjected to a heeling moment M_n and slopes at an angle of heel θ as shown in Fig. 4. When the floating object is tilted, due to the change in the shape of the submerged part of the floating body, the centre of buoyancy C will move to C_1.

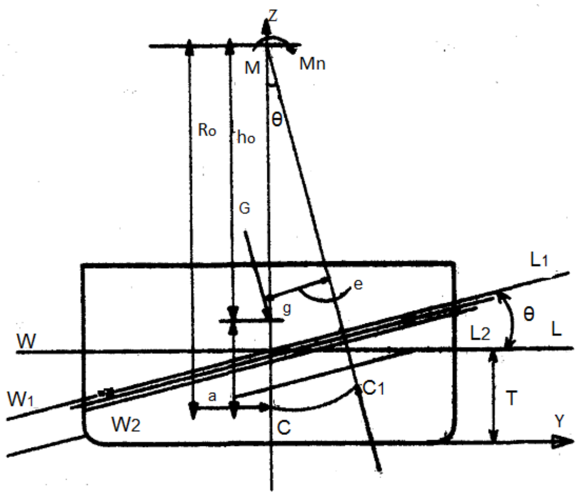

Fig. 4. The inclination of the floating object when subjected to an external torque

The line of effect of the floating force $D = \gamma \cdot V$ cuts the Z-axis at point M. The point M is called the transverse metacentre; the distance from the center of gravity to the transverse metacenter $\overline{Mg}$, is called metacentric height. From Fig. 4, it can be seen that: When the angle of heel θ appears, the force pair G and D will create a moment M whose value is:

$$M = G \cdot \overline{Mg} \cdot \sin\theta \tag{3}$$

This moment is the opposite of the heeling moment M_n and increases similar trend with angle of heel θ. The inclination ends when:

$$M = G \cdot \overline{Mg} \cdot \sin\theta = M_n \tag{4}$$

By mathematical transformations, using the value of the metacentric hight $h_0 = \overline{Mg}$, righting moment M_{kp} calculated according to the formula:

$$M_{kp} = G \cdot h_0 \sin\theta \tag{5}$$

From here it can be seen that the magnitude of the angle of heel is determined by the formula:

$$\sin\theta \approx \theta = \frac{M_n}{G \cdot h_0} = \frac{M_n}{\gamma \cdot V \cdot R_0 \cdot \dfrac{h_0}{R_0}} = \frac{M_n}{\gamma \cdot V \cdot \dfrac{J_x}{V} \cdot \dfrac{h_0}{R_0}} = \frac{M_n}{\gamma \cdot J_x \cdot \eta} \tag{6}$$

in which $R_0 = \dfrac{J_x}{V}$ is the distance from the buoyancy center to the transverse metacentre, J_x is moment of inertia of the waterplane, relative to the axis passing through its center of gravity, $\eta = \dfrac{h_0}{R_0}$ is the ratio between the metacentric hight and the distance from the buoyancy center to the transverse metacentre, V is volume of displacement of the floating object.

In the drilling of mines underwater, there is a plan that the drill can move on the floor, so when calculating the design, the problem of stability of the floating vehicle must be considered when subjected to the tilt torque caused by the eccentric load.

Considering the problem of the drilling machine placed on a floating working platform, the load with weight P set at a fraction of the eccentricity is e_x, it is equivalent to the case where the load is placed at the right center, but the means of subjecting to the effect of incline torque is the value is $M_n = P \cdot e_x$

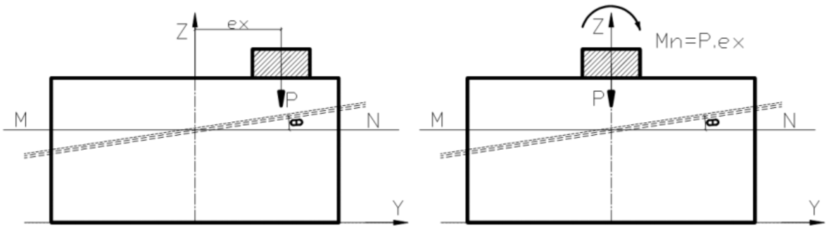

Fig. 5. Floating floor under eccentric load

In the case of the load P is in eccentic relative to the x and y axes, the angle of heel θ and the angle of trim ψ will be in the following formula:

For transverse inclinations, angle of heel: $\theta = \dfrac{P \cdot e_x}{\gamma \cdot J_x \cdot \eta_x}$ (7)

For longitudinal inclinations, the angle of trim: $\psi = \dfrac{P \cdot e_y}{\gamma \cdot J_y \cdot \eta_y}$ (8)

in which J_x, J_y are moment of inertia of the waterplane relative to the Ox axis, Oy passes through its center of gravity; η_x, η_y are the ratio between the metacentric hight and the distance from the buoyancy center to the transverse metacentre (or longitudinal metacentre).

For floating platforms the condition is stable: when subjected to a torque causing inclination, even though the vehicle is tilted, the angle of heel then does not exceed the allowable value, which is the maximum angle without flooding the floor:

For transverse inclinations:

$$\theta_T \le [\theta] \tag{9}$$

$$[\theta] = \text{arctg}\left(\frac{H_s - T}{\frac{B_s}{2}}\right) \tag{10}$$

in which H_s is the height of the floor.

For longitudinal inclinations:

$$\psi_T \le [\psi] \tag{11}$$

$$[\psi] = \text{arctg}\left(\frac{H_s - T}{\frac{L_s}{2}}\right) \tag{12}$$

Working floor ensures stable and dynamic condition: When the drilling machine works, there is inertial force, so the drilling machine acts on the working floor of the floating dynamic force, so when calculating, it is necessary to consider the impact of the drilling machine. The theoretical part presented above only relates to the static stability problem, that is, under the effect of tilting torque, the angle of heel θ increases slowly and without acceleration.

According to the theory presented in the document [1, 2, 3], when the tilting moment acts dynamically, the maximum dynamic angle of heel θ_D will be twice as large as the static angle of heel θ_T, which also generates a static effect on the object floating. So the stable condition when considering the effect of the load is:

For transverse inclinations: $2 \cdot \theta_T = \theta_D \leq [\theta]$ (13)

For longitudinal inclinations: $2 \cdot \psi_T = \psi_D \leq [\psi]$ (14)

3.2. Development of calculation model

Selection of the model for the survey is the plan of a floating working platform with a drill that can be moved on the floor because this plan is more complicated than the plan of a fixed-on-floor drilling machine.

Author proposes a floating platform with a default height equal to the height of the plastic pontoon unit $H_s = 0.43\,\text{m}$. There are 2 similar small holes with the width of one $B_k = 0.5\,\text{m}$ *(equal to the exact width of plastic pontoon unit*), length L_k changing lead to the change of the floor-length L_s. The width of the corridor as $B_{hl} = 1.0\,\text{m}$, $L_{hl} = 1.0\,\text{m}$, enough to ensure smooth operator movement. Choosing a XJ-100 Drilling Machine is popular in the market with the self-weight $P_{mk} = 490\,\text{kg}$. Drill size 1640 x 1030 x 1440 mm. From there, choose the width of the operating area of the drilling machine as $B_m = 2\,\text{m}$, the length of the operating area of the main drill is equal to the length of the hole $L_m = L_k$. The floor is covered with 2-cm thick wooden planks, $p_{pl} = 14\,(\text{kg/m}^2)$. To increase the safety factor, according to the standard [6], the overload factor η_1 = 1.1 for the static load of the floating working floor itself; η_2 = 1.1 for drill load and ancillary equipment, η_3 = 1.3 for humans. Thus the floor width: $B_s^{\min} = B_m + 2 \cdot B_k + 2 \cdot B_{hl} = 2 + 2 \times 0.5 + 2 \times 1.0 = 5\,\text{m}$, while the floor-length L_s changes with $L_s^{\min} = L_m^{\min} + 2 \cdot B_{hl}^{\min} = 4 + 2 \times 1.0 = 6\,\text{m}$.

In the stage of proposing options, it is necessary to determine the appropriate size of the floor to the chosen machine to ensure stable buoyancy and stability conditions. So the calculation must be repeated many times. For convenience in the calculation process, the author has set up an automatic calculation software to assess the buoyancy and stability of the platform. The program follows the theories above by programming language Microsoft Visual Studio. To eliminate the factor of a programming error, Author compared the results of the program with a manual calculation for several examples. The block diagram of the program is shown in Fig. 6. The main programming display of the program is shown in Figs. 7 and 8.

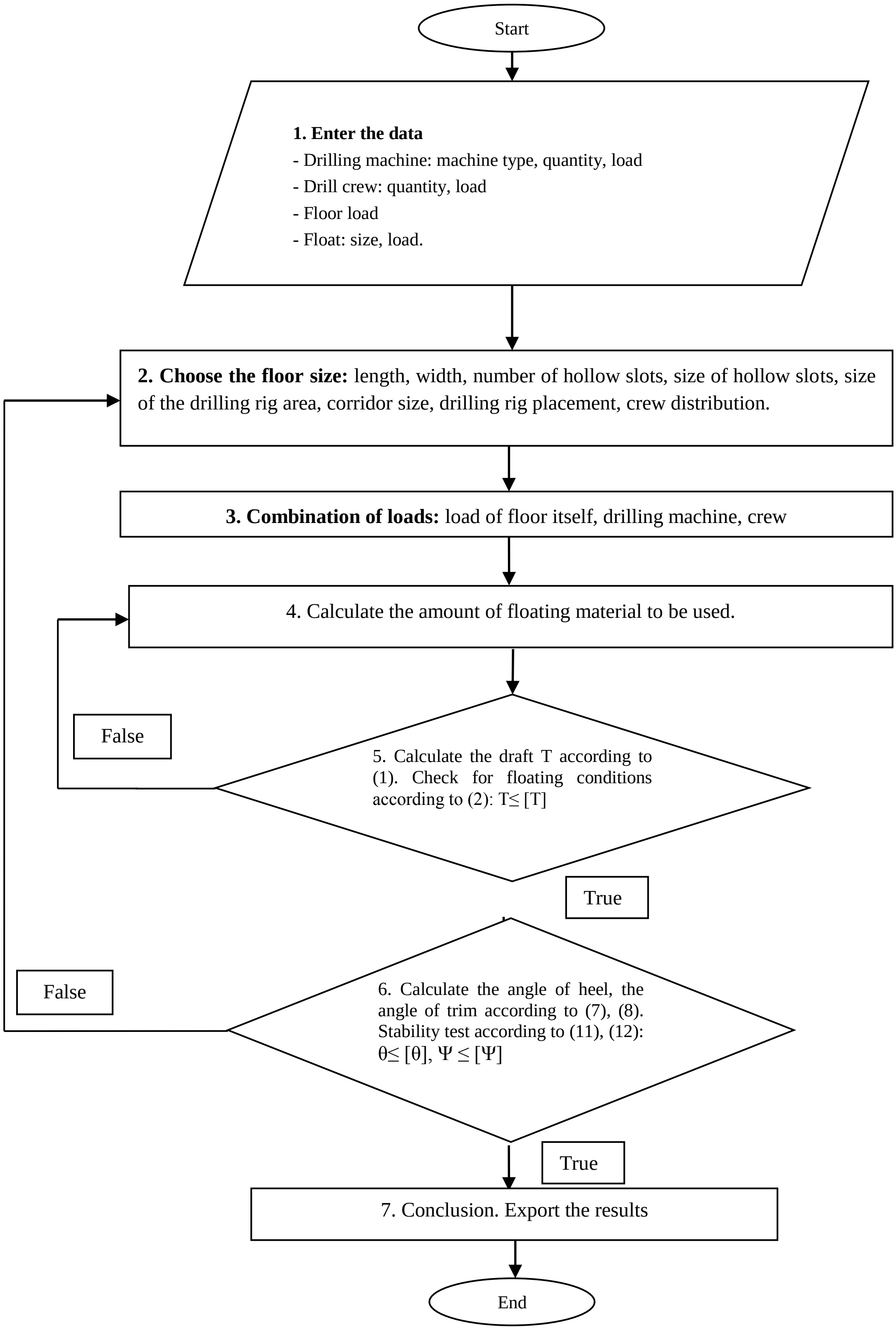

Fig. 6. Block diagram of the program

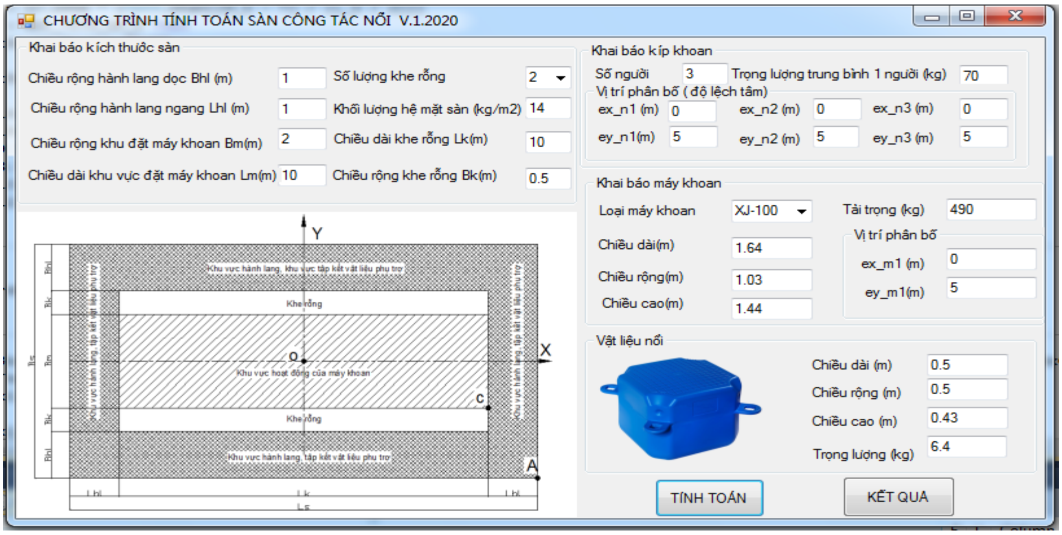

Fig. 7. Data declaration interface

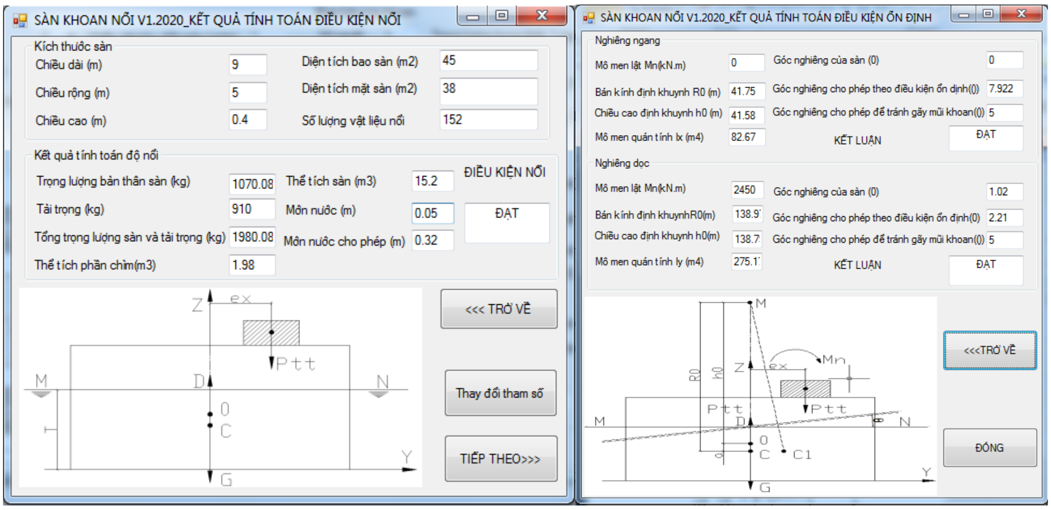

Fig. 8. Interface of floating and steady condition test results

3.3. Survey results

Use this calculator program to examine the floor length changes and the farthest position the drill can be placed to find the right length when the width is known.

Select the survey floor width equal to the minimum value $B_s = B_s^{\min} = 5\,\text{m}$. In the current problem, because the drilling machine can move on the working floor to drill boreholes along the hollow slot, so transversely, the drilling machine is considered to be placed in the center of the floor, that is $e_x = 0$, just change the position of the machine longitudinally, that is to change e$_y$, maximum eccentric value $e_y^{\max} = \dfrac{L_k}{2}$. Thus, only considering the angle of trim ψ.

Tab. 1. Calculation results of some alternatives of the floating working floor from the plastic pontoons

Width B_s, m	Length L_s, m	Draft T, m	Maximum eccentricity e_y^{max}	Maximum angle of trim, ψ degree	Limit angle of trim $[\psi]$, degree	Number of holes drilled (N_{lk}) when the distance between holes			Number of plastic buoys used (N_{pn})
						1m	1.5m	2m	
5	6	0.06	2	1.9	3.20	8	6	4	104
	7	0.06	2.5	1.52	2.79	10	8	6	120
	8	0.05	3	1.23	2.47	12	8	6	136
	9	0.05	3.5	1.02	2.21	14	10	8	152
	10	0.05	4	0.86	2.00	16	12	8	168
	11	0.05	4.5	0.73	1.83	18	12	10	184
	12	0.05	5	0.66	1.68	20	14	10	200
	13	0.05	5.5	0.55	1.56	22	16	12	216
	14	0.04	6	0.5	1.46	24	16	12	232

From the table it shows that the value of the angle of trim ψ decreases as the floor length increases, and then the limit angle of trim $[\psi]$ also decreases gradually, always ensuring stable conditions $\psi \le [\psi]$.

Thus, using the program it is possible to quickly determine the allowable working platform size depending on the particular type of drill.

In addition, considering the number of holes drilled per floor anchoring, the optimal slab size alternative can be found as follows:

- Corresponding to a borehole distance of 1.0 m apart, the optimal option is a floor plan with length $L_s = 14$m based on the ratio of the number of plastic buoys to the lowest number of holes: $\frac{N_{pn}}{N_{lk}} = \frac{232}{24} = 9.6$;

- Corresponding to a borehole distance of 1.0 m apart, the optimal option is a floor plan with length $L_s = 13$m based on the ratio of the number of plastic buoys to the lowest number of holes: $\frac{N_{pn}}{N_{lk}} = \frac{216}{16} = 13.5$;

Corresponding to a borehole distance of 1.0 m apart, the optimal option is a floor plan with length $L_s = 13\text{m}$ based on the ratio of the number of plastic buoys to the lowest number of holes $\frac{N_{pn}}{N_{lk}} = \frac{216}{12} = 18.0$;

Thus, the author recommends choosing the option $L_s = 13\text{m}$ to apply in practice.

The above theoretical calculation is the initial basis to confirm the possibility of applying this working floor plan in practice. In practice, it is recommended that this work platform stability test taking into account dynamic load by allowing the number of revolutions of the drill to increase gradually from the lowest, if instability occurs (inclined floor excess allowable, water spills into the floor), it is necessary to stop to change the floor size or change the position of the drill.

4. Conclusion

Through the study to determine the buoyancy and stability of the floating working floor assembled from the plastic pontoon, it shows the ability to use plastic pontoon to manufacture floating platform is feasible in case of drilling borehole underwater purposes with areas where the water depth is less than 3 m, waves are not more than level 1, and a small capacity drill. The above theoretical calculation is the initial basis to confirm the possibility of applying this working platform in practice.

The appropriate size of the working platform can be determined depending on the specific drilling machine and the optimal choice of the working floor size is based on the criterion of improving the mining efficiency through the number of holes drilled at each floor anchor position. The author recommends choosing the option of floating working platform with width $B_s = 5$ m, length $L_s = 13$ m to apply in practice.

Due to the limited framework of the article, only focus on the matter of buoyancy calculation and stability mentioned above, the author did not mention the calculation and solved many other matters when designing a floating platform made of plastic pontoon such as the matter of optimizing the number of the pontoon, the matter of floating anchors, the effect of waves... The author hopes to exchange to colleagues about this issue for further improvement.

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NGHIÊN CỨU TÍNH TOÁN PHƯƠNG ÁN LẮP GHÉP CÁC PHAO NHỰA NHỎ THÀNH SÀN CÔNG TÁC NỔI PHỤC VỤ VIỆC KHOAN LỖ MÌN DƯỚI NƯỚC

Tóm tắt: *Bài báo trình bày sự tính toán phương án sàn công tác nổi lắp ghép từ phao nhựa nhỏ dùng trong việc khoan lỗ mìn dưới nước. Tác giả sử dụng phần mềm tự lập trình bằng ngôn ngữ lập trình Visual Basic để kiểm tra độ nổi, độ ổn định của sàn công tác. Kết quả khảo sát đã đưa ra phương án hợp lý của sàn công tác nổi để đề xuất áp dụng vào thực tế. Tác giả rút ra kết luận cho phương án được lựa chọn nhằm xây dựng cơ sở khoa học xác định khả năng sử dụng phao nhựa chế tạo sàn công tác nổi dùng cho việc khoan lỗ mìn dưới nước.*

Từ khóa: Phao nhựa; sàn công tác nổi; độ nổi; sự ổn định; khoan lỗ mìn dưới nước.

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