DESIGN AND FABRICATION OF CONCRETE-REINFORCED FLOATING PLATFORM FOR CANAL AND RIVER-SHORE PROTECTION

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Abstract

Erosion of canal and river-shore causes problems on agriculture activities and soil environment. This paper devotes to develop a floating platform to protect the shores. A concrete-reinforced floating platform was designed and fabricated in this study. Mechanical simulation was performed to ensure the design viability. The concrete-reinforced floating platform consists of three main parts: (1) steel structure, (2) foam-cement material, and (3) connecting joints. The dimension of the cement foam floating platform is 1.2 m in width, 3 m in length and 0.4 m in thickness. The cement used in this research is resistant to corrosion of sulfate and chloride from saltwater. Foam with density of 12 kg/m^3 is mixed with concrete matrix so that the floating platform can float 60% or 0.16 m above the water surface. The foam cement material has the maximum compression stress of 1,951 kg ± 266.59 kg for the material density of 427.30 kg/m^3 ± 19.30 kg/m^3. The connecting joint part has the ultimate tensile load of 1,564 kg. The assemble floating platform has the compressive stress of 543.33 kg/m^2 with the maximum vertical deformation of samples of 1 mm under the distribution load of 1,571 over the samples. Finally, from simulation with data from the material testing, the designed floating platform had a safety factor 3.46 which was higher than the design criteria of 3.

Keywords: Concrete-reinforced, Floating platform, Mechanical design, Simulation

Introduction

Today, many countries around the world suffer from the loss of riverbank landings every year. In Southeast Asia, there are several studies on the causes and effects of loss of coastal land. Study of soil bank erosion in ASEAN countries such as Vietnam, land bank losses are caused by wave erosion. These waves caused the development of water transport, resulting in a much greater expansion of water traffic by boats. In addition, bank erosion is caused by climate change, as well as various human livelihood activities that alter the climate and natural environment [1]. Currently, Thailand has many soil erosion problems about the canal and natural river banks. In which these banks were inhabited, agriculture, and natural attractions areas. The erosion of the banks of the canals and rivers has a profound effect on the lives of people living along the waterfront. The erosion of the river banks also has a great impact on the agriculture of farmers in Thailand, resulting in the loss of fertile agricultural land, causing shallow canals and loss of ability to drain the water of canals or river [2]. The problem of soil bank erosion may be the result of natural water currents or waves caused by water traffic by boats or water vehicles that are increasing today, including flooding situations [3]. Riverbank erosion and topsoil loss due to developments in agriculture, water transport, and current climate change. If the data is not collected and studied seriously it can result in irreversible damage to soil resources [4].

The erosion of the river and canal banks, at present, the problem of reducing soil bank erosion has been solved by creating a permanent dam to protect the strength of the water currents and reduce the wave strength caused by water traffic and natural water currents. In some countries, the erosion of water banks is reduced by planting cover crops such as Vetiver Grass or by using other plant species to protect against the waves of tidal currents [5]. Researchers from various countries have created Groyne to block, slow down and change the direction of the current so that the current does not have the speed and direction of the flow, eroding and destroying the riverbank soil directly, reducing the loss of bank soil. Groynes are designed and used to prevent the erosion of river banks caused by currents and flow directions in many countries around the world. Most groynes are designed and installed on the curved banks of the river and are perpendicular to or obstructing the direction of the current flow [6]. Researchers have studied and collected data on the prevention of erosion and erosion of river banks and canals. Based on the results of this study and compilation, the design of floating platforms for protection against currents and waves arising from the movement of boats in rivers and canals is suitable for installation and ease of use. Moreover, floating platforms can float according to the water level in rivers and canals because the water level in rivers and canals is constantly changing. Therefore, the floating platform must be designed to suit the characteristics of the river and be strong enough to withstand the force of the water waves caused by the movement of the boat.

Currently, floating platforms have various designs. A floating platform was designed using cement or concrete to create a floating platform. The density of the floating platform must be less than the density of the water. For example, a floating platform design by outer shell and hollow inner shall with air or foam inside to make it a density lower than water [7]. The floating platform made of whole concrete blocks must be designed to be less dense than water so a very small density material is required. Thus, cement is often mixed with very low-density materials such as EPS foam to make the floating platform able to float above the water level and be strong enough to withstand the load that acting on the floating platform [8]. Most of the load or force comes from the force of the water flow and the waves that hitting the floating platform. The waves may come from the flow of the tides or the movement of the boats. Analysis of the forces that act on a floating platform is analyzed in different ways depending on the behavior of water resources and the environment to install a floating platform [9]. M.S. Kirkgöz has analyzed and calculated the load or the force of the waves exerted on a floating platform or a coastal area. The results of the experiment were performed on variables such as the depth of the water level affecting the force of the wave [10]. H. E. Dempster designed the concrete floating structure by designing the floating platform to float on water with an air gap inside of the floating platform that wrapped in mixed concrete with plastic to make the concrete have a lower density. He designed air gaps inside the floating platform, the floating platform's density is less than the water density, thus enabling the floating platform to float on water [11]. However, limited works have been done on floating platform for rivers and canals to prevent erosion of the soil bank, reduce the loss of topsoil and farmland. Because the force exerting to the rivers and canals are different, the design of the floating platform shall be optimized.

This work focuses on the design and fabrication of a concrete-reinforced floating platform for rivers and canals application. Firstly, the design was done by calculating the forces exerted on the floating platforms by the waves arising from the movement of boats in rivers and canals for the design of steel structures on the inside of the floating platforms which must be able to support the force of the wave not exceeding 14,000 N. The proportions of the foam cement mixture were calculated to have a strength and sufficient density for float ability above the water surface 40%. So the design and calculation of the mixing ratio of the foam cement and the structural steel must have a total density less than 600 kg/m^3. Secondly, the flatform was fabricated steel structure for testing the tensile strength of the floating platform connecting joint, mixing, and casting foam cement cylinders for testing the compressive strength of foam cement materials, and built a floating platform to test the compression and collapse of the floating platform. Then, the samples of each part were subjected to mechanical testing. Finally, the simulation results were compared with the experiment.

Materials and Methods

Raw Material

Steel Structure

Construction steel was used for the internal structure of the floating platform, which is designed to be able to withstand loads as required. It has sufficient mechanical properties for structural design. The weight of the steel structure affects the total density and buoyancy force of the floating platform. The structural steel properties from the manufacturer (Pacific Pipe Public Co., Ltd.) are shown in Table 1.

Table 1. Mechanical Properties of Steel Structure

Property	Value	Unit
Yield strength	400	MPa
Tensile strength	560	MPa
Elastic modulus	200	GPa
Poisson's ratio	0.3	-
Mass density	7,850	kg/ m^3

For reinforcing bar steel using a steel rod SD50 with a diameter of 12 mm which has a yield strength of 490 Mpa. This data is based on the manufacturer (TATA steel Thailand), subject to the tisi 24-2559 standards.

Marine-dry Concrete

A marine-dry concrete with sulfate resistance is suitable for the marine area applications. It has high sulfate and chloride salt. This work used marine- dry concrete sulfate M403S which has good sulfate resistance. Because the floating platform must be able to float on both freshwater and saltwater, the marine-dry concrete has a bulk density of about 1,400 kg/m^3 (manufacturer data: TPI Polene Public Co., Ltd.) that is used for calculating the mixing raw materials to build the cement floating platform.

Polystyrene Foam

Polystyrene foam was utilized as a material for mixing with cement. It is responsible for creating porous in the cement platform since it will be expanded during the production process. Expanded polystyrene (EPS) reduces the weight of the cement platform in its original volume. Therefore, the density of the cement platform is lower. The Properties of EPS foam used in this research is from the manufacturer (Cebau Industries Co., Ltd.) as presented in Table 2.

Table 2. Physical and Mechanical Properties of Expanded Polystyrene (EPS)

Property	Value	Unit
Density	12	kg/m^3
Compressive strength	0.09	MPa
Flexural strength	0.21	MPa
Water Absorption	4	% by volume
Bead Size	3-5	mm

Design and Calculation

Design and calculation of foam cement mix formulas are as follows: the dimensions of the design are 1.2 m width, 3 m length, 0.4 m thickness, equivalent to a volume of 1.44 m^3. The floating platform must be able to float 40% above the surface, which is equal to 0.16 m. Therefore, the design and calculation of the mixing ratio of the foam cement and the structural steel must have a total density less than 600 kg/m^3. Calculation of the weight of the material in the mixture must have the total weight less than 864 kg as shown in Table 3.

Table 3. Mixing Composition of the Material

Cement		**Water**		**EPS Foam**		**Steel**	**Other**	**Total**	**Total**
Volume (m^3)	weight (kg)	Volume (m^3)	weight (kg)	Volume (m^3)	weight (kg)	weight (kg)	Weight (kg)	Weight (kg)	Density (kg/m^3)
0.36	501	0.08	80.064	1.00	12.19	240	30	864	599.3

Cement-foam Mixture

The designed cement foam mixture has the density not exceeding 600 kg/m^3. The w/c ratio is 0.24 with the proportion of the composite material, which is cement 25% by volume, water 6% by volume, and foam 69% by volume. The total weight of the floating platform does not exceed 864 kg consisting of a 593 kg cement-foam composite. Steel structures have a weight not exceeding 240 kg and other materials has a weight lower than 30 kg. The proportion of the mixture makes the floating platform that has a density of 599.3 kg/m^3.

Steel Structure

The weight of the designed steel structure must not exceed 240 kg with dimension as follows: 1.2 m width, 3 m length, and 0.4 m thickness. When casting foam cement, the density of the floating platform does not exceed 600 kg/m^3, which allows the floating platform to float as specified. The internal steel structure model is shown in Figure 1.

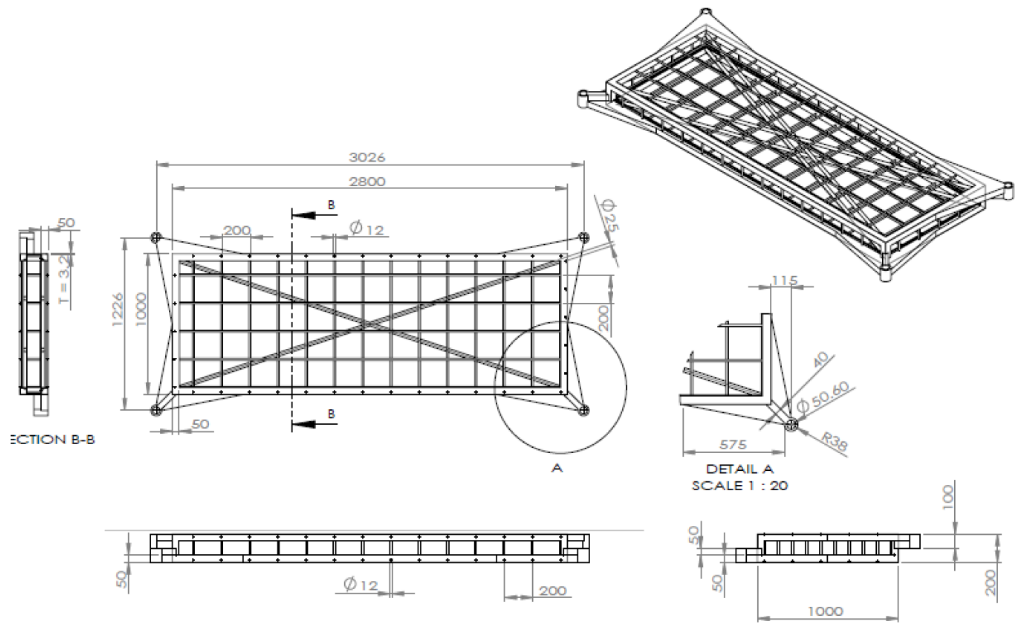


Figure 1. Design of steel structure

Composite Material Fabrication

The Procedure of Mixing Cement Foam

The process of mixing is briefly described in this subsection. The weight of each composition follows the mixing composition ratio in Table 3. First, water was added in the concrete mixing machine. Then, EPS foam was fed and the mixing machine started turning and keep mixing for 1 min. Secondly, cement was added and the mixer was kept turning for 5 min. Then, the mixer was halted to ensure that the mixture was mingled thoroughly by manually scraping out the cement foam attached to the inner surface of the machine. After that, the machine was kept mixing for another 5-min. Finally, the mixture was injected into the mold, compress, and naturally dry for 24 h. The product was removed from the mold and cure in water for 28 d.

Fabrication of Steel Structures and Floating Platforms

The internal steel structure of the floating platform was fabricated from a structural steel by welding according to the production drawing as shown in Figure 1. To fabricate the steel structure, the steel was cut to the size according to the design and then electrically welded by high tensile strength (490 MPa) Familiarc LB-52 electrodes with the welding parameters including electrode diameter 3.2 mm, electric current 100-170 A, and welding speed 40-60 cm/min. After that, the cement foam was mixed according to section 2.3.1 and then cast to cover the steel structure in a rectangular shape with the dimension as follows: 1.2 m in width, 3 m in length and 0.4 m in thickness. After 24 h, the mold was removed and the floating platform was cured with water for 28 d.

Mechanical Property Testing

The foamed concrete specimen was subjected to the compressive test using a hydraulic pressure testing machine shown in Figure 2 according to the ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. The load was continuously applied to the foamed concrete at the rate of 4 mm/min until fracture or damage was detected. The displacement of the compressive testing can be viewed from the measuring instrument on the tester screen and the test result curve. The compressive test was triplicated to ensure the reproducibility of the results. The dimension of cylindrical foamed concrete was 15 cm diameter and 30 cm height.

Figure 2. Hydraulic pressure testing machine**.**

Simulation

Strength of the floating platform and its joints was analyzed by Solidworks simulation program and compared with the experiment results. The strength analysis utilized the finite element method which divided the object into small parts called elements. To precisely analyze the strength of the work piece, this analysis is in the elastic zone phase, so Hook's law analysis is applicable. The normal stress causes normal strain while shear stress causes shear strain. The normal strains produce dilatations while shear strain produces angle deformations. The corresponding mathematical model [12] can be expressed as follows Equation (1)-(3).

$$\varepsilon_x = (dx + \frac{\partial u_x}{\partial x} dx - dx)/\, dx \tag{1}$$

And the normal strains in the y and z-direction are

$$\varepsilon_y = \frac{\partial u_y}{\partial y} \tag{2}$$

$$\varepsilon_z = \frac{\partial u_z}{\partial z} \tag{3}$$

The shear strain value specified as γ_{xy}, expresses the transformation in the square angle amongst AC and AB as shown in [12] and is equal to $\gamma_{xy} = \alpha + \beta$. Further, based on the geometry, the following can be written as Equation (4)-(6).

$$\gamma_{xy} = \alpha + \beta = \frac{\partial u_y}{\partial x} + \frac{\partial u_x}{\partial y} = \gamma_{yx} \tag{4}$$

$$\gamma_{yz} = \frac{\partial u_y}{\partial z} + \frac{\partial u_z}{\partial y} = \gamma_{zy} \tag{5}$$

$$\gamma_{xz} = \frac{\partial u_x}{\partial z} + \frac{\partial u_z}{\partial x} = \gamma_{zx} \tag{6}$$

The normal stresses are identified as principal stresses (P1(σ_1), P2(σ_2) and P3(σ_3)) and are linked to the minimum and maximum stretches. The corresponding strains are known as principal strains (E1(ε_1), E2(ε_2) and E3(ε_3)). Equivalent stress (*von Mises stress*) is frequently used in the design work because it permits any arbitrary three- dimensional stress state characterized by a single positive stress value. Equivalent stress is part of the maximum equivalent stress failure theory used to forecast yielding in a ductile material. Equivalent stress is correlated to the principal stresses by the Equation (7).

$$\sigma_e = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}} \tag{7}$$

And the equivalent strain ε_e (Equivalent strain) is calculated as Equation (8).

$$\varepsilon_e = \frac{1}{1+\nu}\sqrt{\frac{(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2+(\varepsilon_3-\varepsilon_1)^2}{2}} \text{, where } \nu \text{ is Poisson's ratio} \quad (8)$$

The maximum von mises stress criterion is appropriate for ductile materials. It is based on shear-energy theory, which states that a ductile material starts to yield at a position. At that point, von mises stress ($\sigma_{von\ Mises} = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}}$) becomes equal to the stress limit. Generally, the yield strength is used as the stress limit and relate $\sigma_{von\ Mises}$ to σ_{limit}. The factor of safety at a position is calculated as Equation (9).

$$\text{Factor of Safety (FoS)} = \frac{\sigma_{limit}}{\sigma_{von\ Mises}} \quad (9)$$

In the case of pure shear, von Mises stress can be expressed as $\sigma_{von\ Mises} = \sqrt{3}\tau$ Hence, failure arises when $\tau_{\max} = 0.577\sigma_{yield}$.

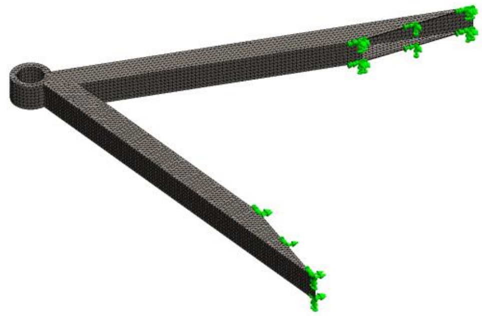
This research has analyzed the strength compared with the experimental results in two parts as follows:

Tensile Strength of The Connecting Joint

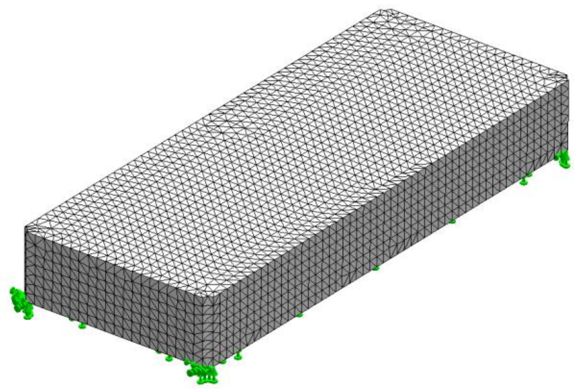
The strength test of the connecting joint was tested by pulling the connecting joint until it was damaged. Therefore, 3D modeling of the connecting joint has been made using a Solidworks simulation program and determined the structural steel materials with mechanical properties as in Table 1. Then, the fixture position was determined based on the actual test characteristics. Meshing of a part with solid elements was done by using linear tetrahedral elements because the workpiece has a straight shape. To obtain an accurate result, strength analysis of all 3D models uses the h-adaptive method for convergence of result which automatically reduces mesh size in areas where the calculated error is high and the target accuracy is 98%. For the connecting joint, the result of strength analysis has numbers of elements were 31,370 elements for 98% accuracy. The fixture position and elements are shown in Figure 3A.

Compressive and Deformation of Foam-cement Floating Platform

The compressive strength testing of the cement foam floating platform was tested by a distributed load on the cross-sectional area of the floating platform. The cross-sectional area is 1.2 m wide and 3.0 m long. The test was done by pressing the object until the deformation displacement occurs according to the design requirements which is equal to 1 mm without breaking or separating the material of the floating platform. The floating platform analysis was based on the actual test data. Solid elements were determined as the linear tetrahedral element because the workpiece is straight. In this simulation, the numbers of elements were 50,549 elements. Meshed floating platform is presented in Figure 3B.



(A)



(B)

Figure 3. Meshing and fixture position of (A) connecting joint; (B) Cement foam floating platform

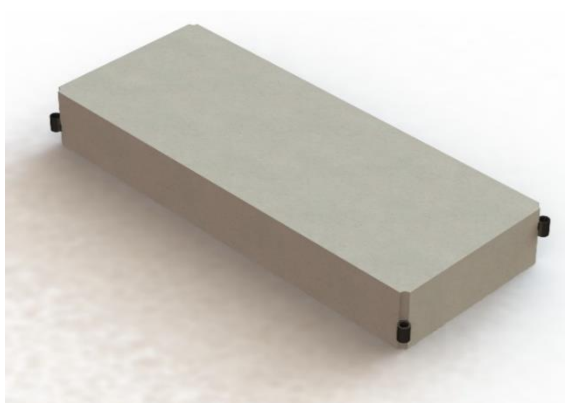
Results and Discussion

Floating Platform Product Overall

The cement foam floating platform is designed to be 1.2 m in width, 3 m in length and 0.4 m in thickness. The steel structure shown in Figure 4A is responsible for the force from the various loads that are applied to the floating platform and also has the function for carrying the load from the attachment points from other parts of the structure. After that, overlay the steel structure with cement foam mixture. P.E. Smith said that the most common approach is to protect the steel with a high-quality concrete, thus prolonging the ingress of the chlorides such that the desired service life is obtained before there is sufficient chloride concentration at the steel location to initiate corrosion. Therefore, it must be designed using cement that covers the steel structure with low penetrability and sufficient thickness of such cover concrete provides this protection. The penetrability and thickness of the cover concrete will be the primary factors in determining whether the service life of a structure will be [13]. M. Thomas said that the cement used for marine structural design must have properties as chloride resistance, freeze-thaw resistance, resistance to sulfates and other chemical attacks, abrasion resistance, and alkalize-aggregate reaction [14]. Therefore, the cement used in this research is resistant to corrosion of sulfate and chloride from saltwater mixed with foam with a density is approximately 12 kg/m^3 so that the floating platform can float 60% or above the water surface, approximately 0.16 meters, which the design must circumscribe and control the design of the cement foam platform and steel structure. Nyal Jennings calculated and designed a floating of the low-density concrete barrier, with foam and fiber-reinforced concrete densities without reinforcement structures lower than the density of the water. The composite material has a density of around 450 kg / m^3 so that the floating platform can float in the water [15]. From the mixing composition of materials in Table 3 which has the density of foam-cement specimens (Figure 4B) as 432.8 kg/m^3. Sergii O. Kroviakov researched and tested the lightweight concrete for floating structures and specified the density of cement composition with reinforced steel structure as 500-600 kg/m^3 [16]. Therefore, this research designed the cement foam floating platform and steel structure with total weight is not more than 864 kg, which makes the floating platform density is 600 kg/m^3 as shown in Figure 4C.

(A)

(B)



(C)

Figure 4. (A) Steel structure; (B) Composite concrete; (C) Floating platform

Floatability of The Floating Platform

The floating test on the water surface of the cement foam floating platform by constructing the cement foam floating platform with internal steel structure to test the floating of the foam cement floating platform in the amount of 3 samples. They floated in the water with a density of about 1,023 kg/m^3, as shown in Figure 5. After that, the distance of the top surface of the floating platform to the water surface was measured. The floating test results of the cement foam floating platform are shown in Table 4.

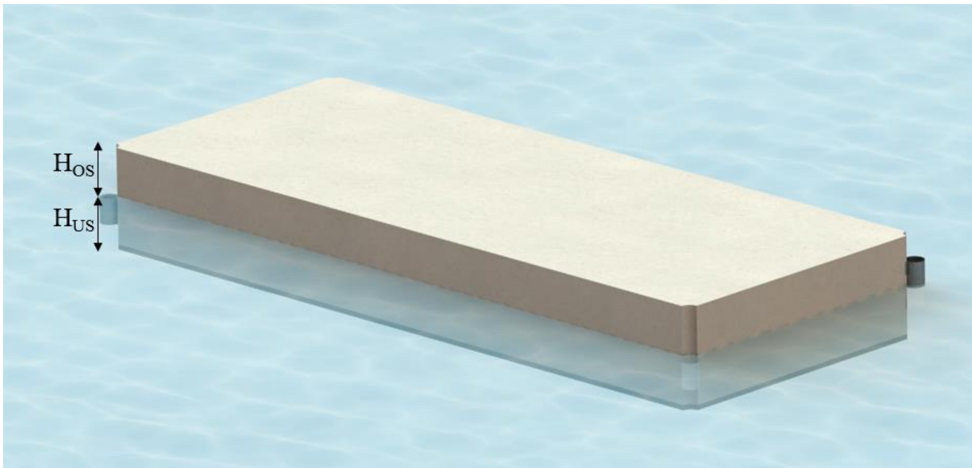


Figure 5. Floating test of the floating platform.

Table 4. Floating Test Result of the Floating Platform

Item	1	2	3	Average
Weight of floating platform (kg)	795	742	774	770.3
Dimension of floating platform; W x L x H (m)	1.22 x 3.01 x 0.39	1.19 x 2.98 x 0.39	1.2 x 3.03 x 0.4	1.2 x 3.0 x 0.393
Volume of floating platform (m^3)	1.432	1.383	1.454	1.423
Floating distance level; H_{OS} (m)	0.183	0.190	0.192	0.188
Buoyancy force (N)	7,999.81	7,731.02	7,670.64	7,800.49
Floating percentage (%)	45.73	47.55	47.96	47.08

The calculated weight of the foam cement platform is 765 kg, consisting of the weight of foam cement 593 kg and the weight of the internal steel structure is 172 kg and the volume is 1.44 m3. From the design and calculation, the floating platform has a buoyancy distance above the water surface (H_{OS}) is equal to 0.192 meters, a buoyancy force equal to 7655.16 N, representing a floating percentage equal to 48.07%. The floating test results of the floating platform compared with the results of the design are deviation was 2.06%.

Mechanical Strength of The Products

Compressive Test of The Foam-cement Product Sample

The testing of foam-cement mechanical properties can be tested by compression testing of composite materials following the ASTM C39 standard test method for compressive strength of cylindrical concrete specimens. The testing sample is 15 cm in diameter and 30 cm in length. The proportion of foam cement mixture consists of 6% water, 69% foam, and 25% cement by volume. To make the sample amount 3 pieces and take 28 days for curing, were tested by the hydraulic compression testing machine. Fang Yonghao et al. performed the investigation on the relationship between the compressive strength and air-void structure of foamed concrete and found that if the amount of air-void in cement foam composite increases, it will also reduce compressive strength. [17]. Helmut Weigler et al. studied about structural lightweight aggregate concrete with reduce density. The results also showed that compressive values also decreased [7]. The compression testing results ordered from the lowest density sample to the highest density sample are shown in Table 5. Averagely, the maximum compression stress was about 1,951 kg ± 266.59 kg for the material density of 427.30 kg/m^3 ± 19.30 kg/m^3.

Table 5. Compressive Strength Testing Condition and Results

No.	Diameter (cm)	Height (cm)	Area (cm^2)	Weight (kg)	Density (kg/m^3)	Ultimate Load (kg)	Ultimate Stress (ksc.)	Remarks
1	15.73	31.50	194.33	2.61	426.37	2,048	10.74	Mixing Ratio
2	15.58	30.20	190.64	2.59	449.86	2,173	11.18	
3	15.62	31.40	191.50	2.74	455.67	2,259	11.80	Cement25% Water 6%
Avg.	15.64	31.03	192.16	2.65	443.97	2160	11.24	Foam 69%
STD	0.063	0.59	1.58	0.066	12.67	86.63	0.43	(by volume)

Tensile Strength Test Result of The Connecting Joint

This research tests the tensile strength of the connecting joints because they are connected to other floating platforms. These connecting joints are responsible for the forces generated by the tides and water waves caused by the movement of small boats in the canal. The wave force is calculated from the wavelength of a small boat movement with an average wavelength of approximately 3.6 meters. The calculation of the moving wave speed is performed on a floating platform with a cross-sectional area equivalent to 1.2 m^2, considering the speed of the waves in deep water, since the depth is greater than 0.5 times the wavelength[18]. We calculate the wave speed equal to 2.37 m/s and then calculate the force acting on the floating platform using a variable formula: water density, wave speed, and cross-sectional area. The value of the force acting on the floating platform is 3,370 N[19]. Based on the results of the calculation of the wave force on the floating platform, it was used as a condition for analyzing and testing the strength of the floating platform connecting joints. In this design, the factor of safety allowance is 4, because the loading and environmental conditions are difficult to estimate[20], so the force that floating platform connecting joint can hold is 13,480 N, or approximately 1,375 kg. The joints must withstand a minimum of 1,400 kg according to the application requirements. The connecting joints have been designed to have the characteristics and dimensions as shown in Figure 6 and tested by pulling the connecting joint until the damage deformation is achieved. The results of the tensile strength testing of the connecting joints as shown in Table 6. The ultimate load for the connecting joint was about 1,564 kg.

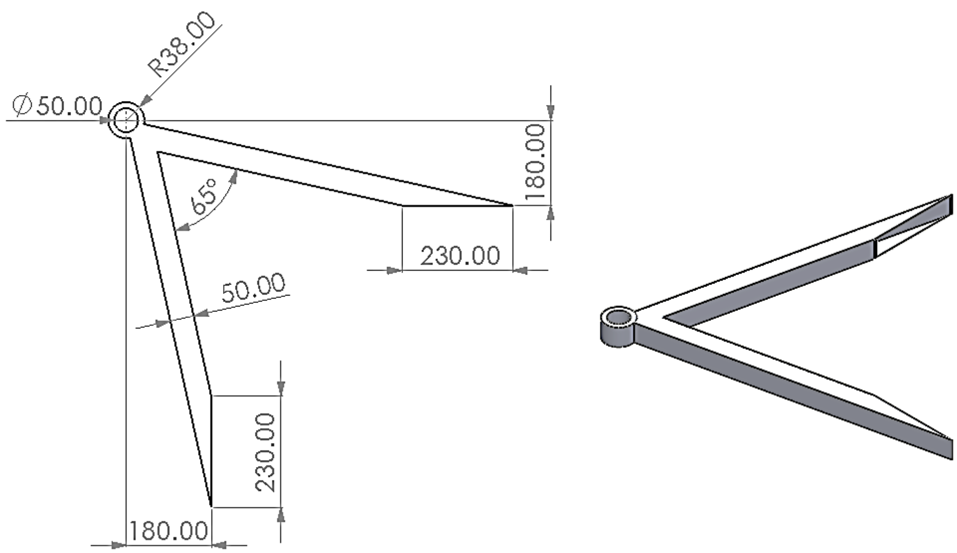


Figure 6. Characteristics and dimensions of connecting joint

Table 6. Tensile Strength Testing Result of Connecting Joint

Specimen	Ultimate Load testing Result (kg.)
1	1,522
2	1,692
3	1,478
Average	1,564

Compressive Test of The Foam-cement Floating Platform

The compressive strength testing of the foam-cement floating platform consists of steel structures and foam cement. The test was performed by pressing the distributed force on the cross-sectional area of the floating platform by using a steel plate on top of the floating platform for testing, as shown in Figure 7.

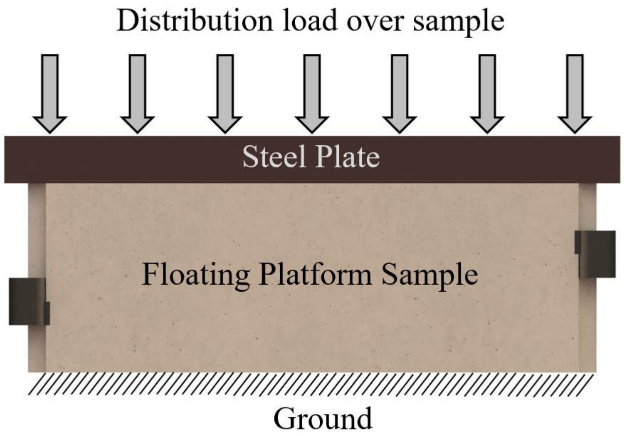


Figure 7. Method of floating platform compressive test

The compressive strength testing of the floating platform was performed until the deformation displacement of the floating platform reaches to 1 mm. The results of the compressive strength test are shown in Table 7, which shows the data respectively from the minimum weight to the maximum weight of the foam cement floating platform. The low weight sample means that the foam proportion of the composite material was high, the density is low, so the value of the compressive stress test was similarly low. The compressive stress was 543.33 kg/m^2 with maximum vertical deformation of samples of 1 mm.

Table 7. Compressive Strength and Deformation Testing Result of Floating Platform

Item	Sample-1	Sample-2	Sample-3	Average
Weight of cement foam floating platform (kg)	847	865	872	861.33
Weight of steel plate (kg)	385	385	385	385
Distribution load over sample (kg)	1,542	1,579	1,592	1,571
Projected top surface area of sample (m^2)	3.6	3.6	3.6	3.6
Compressive stress (kg/m^2)	535.28	545.56	549.17	543.33
Max. vertical deformation of sample (mm)	1.0	1.0	1.0	1.0

Simulation Results

Connecting Joint Strength Simulation Analysis Result

The 3D model and solid element, according to the data in section 2.5.1, are performed to analyze the strength of the connecting joint using the FEA method by determining the value of the force or weight used in the actual testing result in the Table 6. The maximum stress from the analysis was greater than the yield strength of structural steel materials as shown in Table 1. From strength analysis, the load was 15,342 N. and the analysis results as shown in Figure 8. The stress concentration occurs near the circle ring in the expanded picture so maybe fillet or chamfer can be added to distribute the stresses for the better design

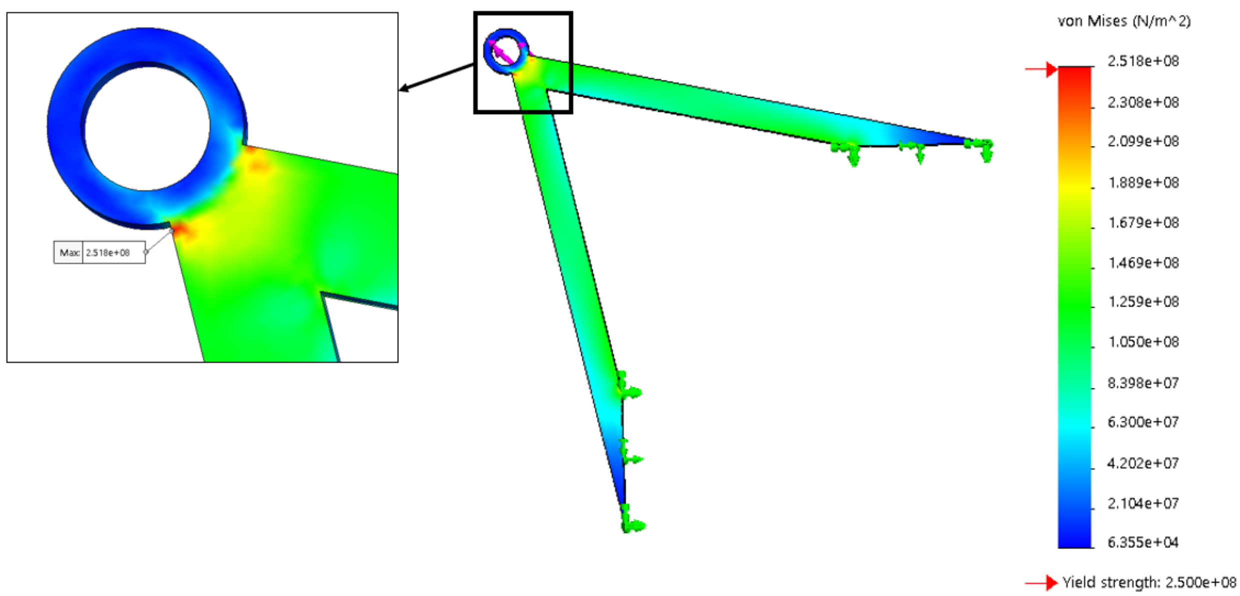


Figure 8. The maximum stress of connecting joint simulation results

The results of analysis by FEM showed that the maximum stress occurred at 252 MPa, which was greater than the yield strength of the steel structure, which was about 250 MPa. The analysis showed that the specifying of the loading force value from the actual test makes the results of the analysis related to cause the deformation as the maximum stress was greater than the yield strength of the structural steel. From the values of the distributed forces in the finite element analysis, compared with the average values of the distributed forces from the actual test results, the error was 0.451%. Based on the actual test results, the first damage location was at the seam between the circular ring and the triangle steel area, which was close to the stress concentration area of the analysis result as illustrated in Figure 8.

Compressive Strength and Deformation Analysis Result of Floating Platform

This research analyzed the deformation of the cement foam floating platform by particularizing the average distribution load from the actual test at 1,956 kg. From the actual test result, the deformation displacement was 1 mm. From the Solidworks simulation program, the maximum deformation displacement was 1.072 mm representing a 7% tolerance compared to the actual test in Table 7. The simulation analyses distribution force loading for the collapse displacement to compare with the actual test. In this analysis, there was a fairly uniform distribution of forces and stresses to support the distribution forces. The Floating platform compressive stress simulation results are shown in Figure 9.

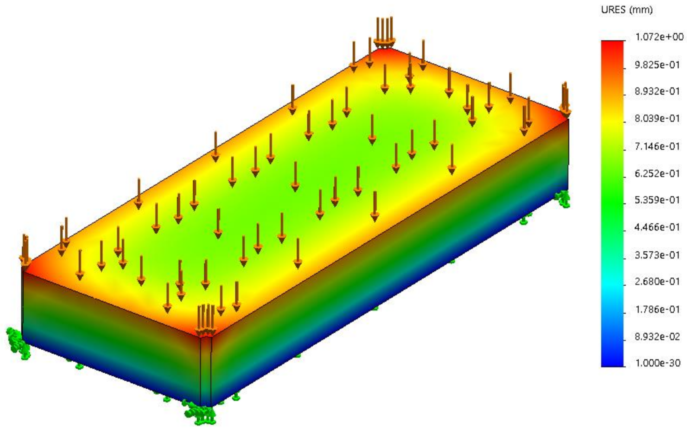


Figure 9. Floating platform compressive stress simulation results.

Floating Platform Steel Structure Stress Analysis Result

The above actual testing and analysis results show that the position of the steel structure that has the highest stress value is the position on the part of the connecting joint. Because the testing and analysis results were tested and analyzed according to the requirements of the floating platform design. The results show that the floating platform was strong enough to meet the design requirements. This research has designed the steel structure of this floating platform to be strong enough. Results from the strength analysis was comparable with the actual test. The comparison of the analysis results with the actual test results was reliable and acceptable. The design requirements for the floating platform to be able to operate safely must have a factor of safety not less than 3. M Pricop stated that factors of safety in offshore structures design according to environmental loads suitable for designing structural types as semisubmersible platform, the factor of safety should be at least 3 [21]. Additionally, R Maria reported that the general recommendation for application usage in the factor of safety consideration if the structure used with materials where properties are not reliable and the environmental loading are not severe, the factor of safety should be at least 3[21]. After designing the steel structure and analyzing the strength of the steel structure, the analysis results are shown in Figure 10.

Figure 10 shows that the analysis of the steel structure by determining the value of the tension force on the connecting joint of the floating platform on both sides. By specifying the value of the tensile force 1400 kg per side and holding the other 2 connecting joints, the results of strength analysis of the steel structure had the maximum stress of 72.2 MPa. This yielded the factor of safety of 3.46 which was more than the factor of safety according to the design requirements. This design has stress concentration points that are mostly located on the corner with less than or equal to a right angle which can add parts to support the force in that area to distribute the stress. From the design and analysis of the strength and properties of the floating platform for protection against the force of waves causing the erosion of river banks and canals. It can be seen that what has been calculated and designed is important for the strength of the floating platform. The steel structure and the floating platform connecting joint sufficiently to withstand the wave force of the movement of boats in rivers and canals.

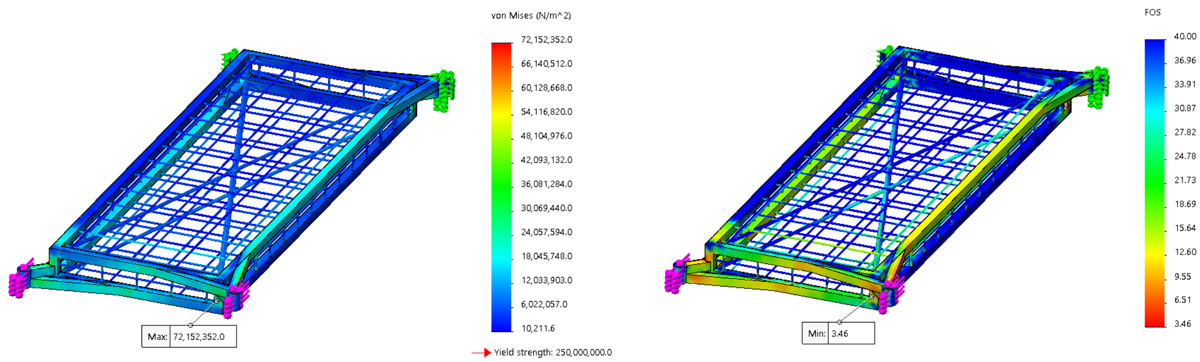


Figure 10. Steel structure simulation results.

Conclusions

This research designed and fabricated a concrete-reinforced floating platform with mechanical simulation. The floating platform consists of three important parts: (1) steel structure, (2) foam-cement material, and (3) connecting joints. Conclusion can be made as follows:

1. The cement foam floating platform is designed to be 1.2 m in width, 3 m in length and 0.4 m in thickness. the cement used in this research is resistant to corrosion of sulfate and chloride from saltwater mixed with foam with a density is approximately 12 kg/m^3 so that the floating platform can float 60% or above the water surface, approximately 0.16 meters

2. From compressive test of foam cement material, the maximum compression stress was about 1,951 kg ± 266.59 kg for the material density of 427.30 kg/m^3 ± 19.30 kg/m^3. From tensile strength test of joint material, the ultimate load for the connecting joint was about 1,564 kg. After assemble the floating platform product, the compressive stress was 543.33 kg/m^2 with maximum vertical deformation of samples of 1 mm under the distribution load of 1,571 over the samples.

3. From simulation results of the floating platform using the data from material testing, the designed floating platform had a safety factor 3.46 which was higher than the design criteria of 3.

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