Oil-palm empty fruit bunch fiber reinforcement in concrete-foam application for floating platform

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Abstract. This paper focuses on fiber reinforcement of concrete-foam material (CFM) for floating platform. Oil-palm empty fruit bunch fiber (EFB-F) was selected to mix with CFM. Initially, three composition ratios of CFM were produced and tested to optimize the curing time. Then, the EFB-F was mixed with the optimized CFM. Several ratios of EFB-F and optimized CFM were used to study the effect of fiber reinforcement. Mechanical properties namely, compressive strength and tensile strength from flexural test were investigated. Several designs and compositions of the floating platform were studied to optimize strength and floatability (as composite material density). The research and testing results, it can be concluded that the cement-foam-EBF-F composite material has a higher density, resulting in higher compressive strength and tensile strength. Therefore, Oil-palm empty fruit bunch fiber, a waste material from manufacturing processes, can be utilized as an ingredient to improve the mechanical properties of foam cement for floating platforms.

1. Introduction
Currently, floating platforms are designed and made to be utilized in various fields such as water activities, prevent coastal erosion from waves, etc. The design and material selection of floating platforms for various purposes differs depending on the force load that acting on the structure of the floating platform, such as floating platforms made from Polymer materials are used for small water pathways or water activities[1] or composite materials such as lightweight concrete reinforced with steel structure to support the load of water waves that acted to floating platforms.

This research has studied materials suitable for supporting the force of waves to make floating platforms. The density of the foam cement was less than the water density of 1,000 kg/m³, but due to the mechanical properties of the foam cement, it was not high on the bending tensile strength. Therefore, the concept of improving the mechanical properties of this composite can withstand greater tensile strength by incorporating fibers to support cement and foam adhesion[2].

The fibers mixed with foam cement in this research are made from natural fibers. Many natural fibers can withstand high tensile strength. This work focuses on the natural fibers leftover from the utilization process. In this research, oil palm fibers were selected, which in Thailand has large amount of oil palm products.[3]

Oil palm fibers mixed with foam cement to improve the mechanical properties of bending tensile strength for use as floating platform material. It is the use of waste from natural product production processes that are abundant in the country to benefit and reduce the number of chemical materials used. This research will perform a compressive test and flexural test to compare the mechanical properties of
compression and tensile strength of composite materials with different densities. This is to be used for further analysis and design of materials for floating platforms.

2. Materials and Methods

2.1. Raw Material

The materials used for mixing and constructing the specimens for this test are cement and foam as the main materials used to make floating platforms. Cement must be able to resist the corrosion of the chemical ingredients present in natural water. The main chemical constituents of natural water sources are sulphate and chloride. The foam has a very low density and is round granular. When mixed with cement, the density of the composite is lower than that of water. Mechanical properties and foam reduction are improved by using natural materials left over from the manufacturing process, namely oil-palm empty fruit bunch fiber (EFB-F). The properties of the three materials are as follows.

2.1.1. 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$^3$ that is used for calculating the mixing raw materials to build the cement floating platform.

2.1.2. 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 EPS foam that used in this research has bulk density as 30 kg/m$^3$ [4] and it has the physical and mechanical properties as shown in [5].

2.1.3. Oil-palm empty fruit bunch fiber. EFB-F is a natural material leftover from the processing of oil palm for use. Therefore, the residues from the aforementioned processes that are natural fibers are used for benefit. It is applied to improve the mechanical properties of foam cement for the floating platform in terms of tensile strength. The EFB-F have mechanical properties as shown in [6].

2.2. Mixing composition calculation

2.2.1. Mixing composition of cement-foam. The three formulas of cement-foam were mixed with a w/c (water : cement ratio) of approximately 0.3, and they were formulated with different densities and less than the water density, which was 1,000 kg/m$^3$. The composite materials must use for creating a floating platform. Proportions for mixing cement-foam composition are shown in Table 1.

| Sample Type | Mixing Composition (%by volume) | Density (kg/m$^3$) |
|-------------|---------------------------------|-------------------|
| F1          | 32.00 | 9.60 | 58.40 | 100.00 | 440 |
| F2          | 40.00 | 12.00 | 48.00 | 100.00 | 550 |
| F3          | 44.00 | 13.20 | 42.80 | 100.00 | 600 |

2.2.2. Mixing composition of cement-foam-EFB-F. EFB-F were mixed with the three above formulas of cement foam by reducing the amount of foam and replacing it with EFB-F by adding 1% by volume and
2% by volume of the composite material as shown in Table 2. EFB-F are used to mix with cement foam cut to a length of 1-3 cm.

**Table 2. Mixing composition of cement-foam-EBF-F**

| Sample Type | Cement (%) | Water (%) | Foam (%) | EBF-F (%) | Total (%) | Density (kg/m³) |
|-------------|------------|-----------|----------|-----------|-----------|----------------|
| PF11        | 32.00      | 9.60      | 57.40    | 1.00      | 100.00    | 460            |
| PF12        | 40.00      | 12.00     | 47.00    | 1.00      | 100.00    | 560            |
| PF13        | 44.00      | 13.20     | 41.80    | 1.00      | 100.00    | 620            |
| PF21        | 32.00      | 9.60      | 56.40    | 2.00      | 100.00    | 490            |
| PF22        | 40.00      | 12.00     | 46.00    | 2.00      | 100.00    | 580            |
| PF33        | 44.00      | 13.20     | 40.80    | 2.00      | 100.00    | 630            |

2.3. Composite material fabrication

Mixing the proportions of cement-foam in Table 3 and cement-foam-EBF-F in Table 4 by mixing cubical specimens of 50 x 50 x 50 mm for compressive strength test as shown in Figure 1 and cross-section size of 50x50 mm, length 150 mm for the three-point bending flexural test shown in Figure 2 and mix 3 cube specimens per each formula. A mortar mixer was used to mix various materials together, then it was cured with moisture for 28 days before testing.

*Figure 1*. cubical specimens of 50 x 50 x 50 mm for compressive strength test

*Figure 2*. specimens for the three-point bending flexural test
2.4. Mechanical property testing

Testing was conducted to compare the mechanical properties of composite materials in various Formulas. The experiment will test the compressive test and flexural test with a universal testing machine as Shimadzu Model AG-X Plus with maximum loading 5 tons which can make a test with accurate, reliable testing results.

2.4.1. Compressive test. Compression test is done according to ASTM C109 standard[7] for comparing the compressive strength values of test specimens with different densities and mixtures as shown in Table 1 and 2 by testing with a universal testing machine (Shimadzu Model AG-X Plus), the test results obtained from the universal testing machine were the values of the force and stroke or displacement, then the values obtained from the universal testing machine were used to create a Stress-Strain curve using the formula for calculating the stress value as $\sigma = \frac{F}{A}$ and strain calculated by $\varepsilon = \frac{\Delta L}{L}$. Preparation of the test is shown in Figure 3. The Poisson's ratio of each formulation of foam cement mixtures can be calculated by measuring the changing dimensions of the specimen in two dimensions.

![Figure 3. Compressive test set up](image)

2.4.2. Flexural test. Flexural test is done according to ASTM C293 standard[8] for bending of materials. The test results showed that the tensile stress occurred. Most of the time, they were tested to determine the tensile strength of materials with relatively brittle properties. The bending test is performed using a universal testing machine by preparing the test shown in Figure 4. The three-point bending flexural test was performed. The values obtained by the test apparatus derived from the force loading in the center of the beam and the value of the vertical deflection. This test can find the stress value from the equation $\sigma = \frac{3FL}{2bd^2}$, where F is the force obtained from the universal testing machine. Then, the strain value was derived from the equation $\varepsilon = \frac{6Dd}{L^2}$, where D is the stroke or displacement obtained from the universal testing machine.
3. Result and Discussion

3.1. Mechanical testing result

3.1.1. Compressive testing result. After testing the compressive strength of composite materials in different proportions, the compressive strength is proportional to the density of the composite material, the results of the test after calculated by the equations in subsection 2.4.1. are shown in the graph in Figure 5. For the compressive strength test, the results showed that cement-foam with a density of 440 kg/m$^3$, 550 kg/m$^3$, and 600 kg/m$^3$ have compressive strengths of 0.0085 MPa, 0.041 MPa, and 0.141 MPa, respectively. The composite materials for floating platform from EFB-F reinforced concrete-foam materials with density of 440 kg/m$^3$, 550 kg/m$^3$, and 600 kg/m$^3$ have compressive strength (EFB-F 1%) of 0.025, 0.08, and 0.26 MPa, respectively and have compressive strength (EFB-F 2%) of 0.038, 0.23, and 0.32 MPa, respectively. It was seen that if the cement-foam composite material had a higher density, it would also have a higher compressive strength. The graph in Figure 5 shows that when mixed with Oil-palm empty fruit bunch fiber added to replace the foam. Composite materials have higher compressive strength and composite materials have higher densities.
The graph in Figure 5 shows the comparison of compressive stress arising from various formulas testing with different mix proportions, it can be seen that the formulas with higher density have a higher compressive stress value because of the higher content of cement. Moreover, adding EFB-F to the mixture instead of foam content resulted in higher compressive stress values. Poisson's ratio of each formulation of foam cement mixtures was approximately the same at 0.31. Poisson's ratio of materials in each formulation of palm foam cement was slightly less than that of foam cement, approximately 0.29, possibly due to the tensile properties of oil-palm empty fruit bunch fibers, resulting in a smaller expansion of specimen that Poisson's ratio is lower.

3.1.2. Flexural testing result. Flexural test to analyze the tensile strength of the composite material that can be calculated by the equations in subsection 2.4.2. The graph in Figure 6 shows that the flexural test, in order to test the tensile strength of the composite material. The results showed that cement-foam with a density of 440 kg/m$^3$, 550 kg/m$^3$, and 600 kg/m$^3$ had tensile strength of 0.035 MPa, 0.048 MPa, and 0.08 MPa, respectively. The composite materials for floating platform from EFB-F reinforced concrete-foam materials with density of 440 kg/m$^3$, 550 kg/m$^3$, and 600 kg/m$^3$ have tensile strength (EFB-F 1%) of 0.045, 0.083, and 0.16 MPa, respectively and have tensile strength (EFB-F 2%) of 0.053, 0.22, and 0.38 MPa, respectively. Stress was higher as the material has a higher density. Additionally, the EFB-F-based composites had higher stress than that of the non-palm fiber formulas. And when the EFB-F content was greater, the composite material had a higher tensile strength.

![Tensile Stress-Density Curve](image)

Figure 6. Tensile stress-density curve

4. Conclusions
To calculate the formula of a composite to make a floating platform, it is important to consider the density value, less density than that of water. In this research, foam cement materials were used to give the composite material a density lower than that of water. The formula was calculated to create a test specimen with a density of approximately 440 kg/m$^3$, 550 kg/m$^3$, and 600 kg/m$^3$, various formulas were w/c equal to 0.3. This research was added Oil-palm empty fruit bunch fiber to replace foam as 1% and 2% by volume. From the research and testing results, it can be concluded that the cement-foam- Oil palm empty fruit bunch fiber composite material has a higher density, resulting in higher compressive strength and tensile strength. Therefore, Oil-palm empty fruit bunch fiber, a waste material from
manufacturing processes, can be utilized as an ingredient to improve the mechanical properties of foam cement for floating platforms.

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