Study on Workability High Strength Concrete Containing Pineapple Leaf Fiber (PALF)

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Abstract. The addition of fibers in concrete increases bridging force in interfacial transition zones inside the concrete matrix. Pineapple Leaf Fiber (PALF) is a natural fiber that has the potential to replace artificial fibers as reinforcement on concrete. As reinforcement fiber in concrete, PALF will undergo fibrillation and water absorption in concrete mixture and will change the mechanical properties of fresh concrete. So, the purpose of this study is to study the workability characteristics of fresh state concrete given PALF. Some variations of PALF composition are 0.04, 0.09, and 0.15 % wt. of cement is mixed into fresh concrete mixture with water-cement (w/c) ratio variations of 0.35, 0.38, and 0.41. The planned concrete is high-strength concrete, then the provisions of determination of coarse and fine aggregates using sieve analysis according to high-strength concrete material standards and concrete mixtures are given superplasticizer 0.09% wt. of cement constantly for all mixtures. A slump test method is still an option in this study, where this method becomes the standard to determine workability effectively. The results showed that an increase in concrete strength was achieved in the addition of PALF composition in concrete compared to control (normal concrete), in addition to the tendency of the relationship between w/c ratio, slump value, and compressive strength in all PALF variations achieved in this study.

1. Introduction
Concrete has a higher compressive strength property than tensile strength. Factually, the concrete will withstand tensile when weighed down, especially on distressed rear surfaces. Concrete is brittle, when a crack occurs, then stress cannot be transferred anymore and concrete will failure instantly. The strength of concrete will depend on the bond between the aggregates in the concrete matrix [1], then the crack that occurs arises from microcrack or shear stress in the interfacial transition zone (ITZ) between the aggregates where this area is the weakest in the concrete matrix.

Many studies were conducted to improve the weaknesses in this area, one of the efforts is the addition of fibers into the concrete to increase the strength of concrete [2][3][4]. Fibers in concrete will increase the interfacial between aggregates. However, in reality, the presence of fiber in concrete will affect the workability performance of concrete. Fiber will occur fibrillation [4][5] and affect the moisture content in the concrete mixture due to absorption by fiber thus affecting the slump value [6]. The presence of fiber in the concrete mixture creates friction between the fiber and the concrete particles and inhibits the flow of fresh concrete. Therefore, large quantities are not recommended and can result in shafts in concrete. But in certain cases in lightweight concrete, fiber can increase workability since it effectively
restrains the segregation, although fiber lowers the slump value [7]. In the meantime, the effect of absorption can be reduced by adding extra water following the absorption of fiber.

In this study, the fiber used is Pineapple Leaf Fiber (PALF) which is abundant and wasted. PALF has good properties [8] and can be used as reinforced fiber in concrete. PALF is a natural fiber, which can absorb water and affect the water-cement (w/c) ratio of concrete and it is easy to have fibrillation. Therefore, this study investigated the influence of PALF on the workability of high-strength concrete, further exploring the slump character of high-strength concrete mixtures containing PALF with w/c cement variations.

2. Materials and methods

2.1. Materials
The materials used to develop high-strength concrete in this study, through several requirements of the Indonesian National Standard and ASTM. Coarse and fine aggregates through the test stages as shown in table 1. This is very important because aggregate is the basic material of concrete and must have good quality before it becomes high-quality concrete. Sieve analysis can determine Fine Modulus (FM) coarse and fine aggregate [9], and several other tests to determine aggregate and cement properties such as density, bulk density, specific gravity, and absorption [10].

PALF used as concrete fiber has a composition of 0.04%, 0.09%, and 0.15% wt. of cement. Pineapple leaf fibers are produced by manual [11]. The fibers are obtained by separating the fibers in the leaves with the outermost layer of the leaves, then the fibers are dried and the result is as in Figure 1. The chemical properties of PALF had determined experimentally by [12] and [8]. The physical and mechanical properties of PALF based on its density were reviewed and reported by [11] and [8]. The properties of PALF as in Table 2, which in this study, the PALF used has a diameter of 12 micrometers.

![Figure 1. PALF used in the study taken from pineapple leaves.](image)

Table 1. Properties of the constituent material of concrete.

|                     | Coarse Aggregate | Fine Aggregate | Cement | PALF |
|---------------------|------------------|----------------|--------|------|
| Fine Modulus (FM)   | 7.068            | 2.775          | -      | -    |
| Density (gr/cm³)    | 2.716            | 2.571          | 1.439  | -    |
| Specific Gravity (gr/cm³) | -              | -              | 3.102  | -    |
| Bulk Density (gr/cm³) | 1.511          | 1.165          | -      | -    |
| Water content (%)   | 0.604            | 2.145          | -      | -    |
| Absorption (%)      | 0.752            | 1.730          | -      | 5.27 |
| Mud Content (%)     | 0.767            | 3.3            | -      | -    |
| Maximum diameter (mm) | 40              | 2.36           | -      | -    |
| Abrasion (%)        | 16.460           | -              | -      | -    |
Table 2. Physical properties of PALF [8].

| Fiber diameter (Micrometer) | Tensile Strength (Mpa) | Young’s Modulus (Gpa) | Elongation (%) |
|-----------------------------|------------------------|-----------------------|----------------|
| 5.0–30.0                    | 170                    | 6.26                  | 0.8 – 1.6     |
| 105–300                     | 293.08                 | 18.934                | 1.41           |
| 50–91                       | 210–695                | 15–53                 | -              |
| 60–6                        | 413–8                  | 6.2                   | 1.6            |
| 30–60                       | 413                    | 6.5                   | 1.6            |
| 20–8                        | 413–1627               | 34.5–82.5             | 1.6            |

2.2 Mix Design of Concrete and Experimental methods

Concrete mix planning based on Indonesian National Standard [13] as in table 3. The samples of concrete were produced in form of cubes with a size of 15cm x 15cm x 15cm, with a total of 24 sampleseach for three treatment ages: 7 days, 14 days, and 28 days.

Table 3. Mix proportions of concrete.

| PALF (% wt. cement) | w/c | Cement (Kg/m³) | Fine Aggregate (Kg/m³) | Coarse Aggregate (Kg/m³) | Superplasticizer (% wt. cement) |
|---------------------|-----|----------------|------------------------|--------------------------|--------------------------------|
| 0                   | 0.35| 485.00        | 574.85                 | 1213.65                  | 0.09                           |
| 0                   | 0.38| 447.37        | 605.04                 | 1221.47                  | 0.09                           |
| 0                   | 0.41| 414.63        | 625.22                 | 1234.11                  | 0.09                           |
| 0.04                | 0.35| 485.00        | 574.85                 | 1213.65                  | 0.09                           |
| 0.04                | 0.38| 447.37        | 605.04                 | 1221.47                  | 0.09                           |
| 0.04                | 0.41| 414.63        | 625.22                 | 1234.11                  | 0.09                           |
| 0.09                | 0.35| 485.00        | 574.85                 | 1213.65                  | 0.09                           |
| 0.09                | 0.38| 447.37        | 605.04                 | 1221.47                  | 0.09                           |
| 0.09                | 0.41| 414.63        | 625.22                 | 1234.11                  | 0.09                           |
| 0.15                | 0.35| 485.00        | 574.85                 | 1213.65                  | 0.09                           |
| 0.15                | 0.38| 447.37        | 605.04                 | 1221.47                  | 0.09                           |
| 0.15                | 0.41| 414.63        | 625.22                 | 1234.11                  | 0.09                           |

3. Results and discussion

3.1 Sieve analysis

Aggregate gradation plays an important role in forming high-quality concrete [14]. In figure 2 and Figure 3, it is shown that the aggregate is within the required range (sufficient) for coarse and fine aggregate respectively [15]. Usually, fine modulus (FM) is determined for fine aggregate analysis, but in this study, fine and coarse aggregate combined although in the analysis determine FM separated [16]. The merger of overall gradations [17] resulting in very small stage zones and using only a nominal maximum aggregate of 20 mm. By using ASTM C33[16], the aggregate ratio will be wider to determinethe slump and varying strength.

Figures 2 and 3 use a logarithmic scale, showing that the percentage distribution passes the maximum sieve of coarse aggregate is the sieve pass number 38.1 mm [18], and the normal distribution of the percentage passes fine aggregate sieve is rather rough sand [18] with an FM of 2,775. In the combinationof these two aggregates, it has a moderate mixed gradation and has a mixed FM of 5.5. All aggregate sizes can certainly fill the space on the concrete matrix evenly. Furthermore, the sieve analysis can determine the quality of concrete to be produced.
3.2. Workability performance and \( w/c \) Ratio

The workability mix with various \( w/c \) ratios of PALF concrete as shown in table 4 indicates the slump mix of the concrete mixes ranges from 30 to 45 mm. This slump is generally called a low slump, where these results are influenced by the \( w/c \) ratio, PALF presence, and superplasticizer in concrete. However, the composition of the superplasticizer on the overall concrete mix is constant.

The results showed the lowest \( w/c \) ratio of 0.35 had the lowest slump value and at a high \( w/c \) ratio of 0.41 on normal concrete had a high slump. Figure 4 shows the tendency of slump value influenced by \( w/c \) ratio in each variation of concrete PALF. At \( w/c \) ratio 0.35 for all concrete mixes have a low value, but it can be seen that in concrete PALF variation is lower than control. This is a similar finding by the previous experiment by using fiber material as an addition to concrete [18,19,20], here it is clear that the use of fiber on concrete will reduce the slump value. The effect of fiber in a mixture is seen in figure 4, where the slump value in the mixture contains lower fiber than concrete without fiber. The presence of fiber will affect the viscosity of fresh concrete as found by Aydin [21], that the addition of carbon fiber
changes the mix of concrete, the more fiber the viscosity will decrease, even for artificial fiber such as steel fiber will affect the value of slump [21].

Table 4. Slump test results.

| Composition of PALF (%) wt. of cement | 0     | 0.04 | 0.09 | 0.15 |
|-------------------------------------|-------|------|------|------|
| Avg. Slump Height (mm) w/c Ratio 0.35 | 35    | 33   | 30   | 33   |
| Avg. Slump Height (mm) w/c Ratio 0.38 | 40    | 43   | 38   | 35   |
| Avg. Slump Height (mm) w/c Ratio 0.41 | 45    | 45   | 40   | 40   |

Figure 4. The tendency of workability mix with various w/c ratios of PALF Concrete.

3.3. Compressive strength vs concrete ages

Figures 5 to 7 show compressive strength of concrete with PALF variations and w/c ratios of 0.35, 0.38, and 0.41 respectively. In all w/c ratios, concrete with PALF variation of 0.09% has the highest strength then decreases at PALF 0.15%. The presence of fiber helps in bridging microcracks on concrete [5][22], thus increasing the strength of concrete, however, when the fiber content is not appropriate or excessive it will decrease the strength of the concrete [21][22][23].

At w/c the ratio of 0.35 has the highest concrete strength compared to other w/c ratios. It agrees with the previous study [24], that the strength of concrete is expressed as a function of time and w/c ratio, decreasing the w/c ratio will be increasing of concrete strength, as well as increasing strength of concrete along with the length of time.

Figure 5. Compressive Strength of various PALF in concrete with w/c ratio 0.35 according to the age of concrete.
Figure 6. Compressive Strength of various PALF in concrete with w/c ratio 0.38 according to the age of concrete.

Figure 7. Compressive Strength of various PALF in concrete with w/c ratio 0.41 according to the age of concrete.

3.4. Relation between compressive strength, w/c ratio, and slump for variation of PALF

Figures 8 to 11 show PALF variations in concrete: control, 0.04%, 0.09%, and 0.15% respectively indicating a relation between a decrease in concrete strength to an increase in w/c ratio, and also a relation between the tendency of increased slump value to the increase in w/c ratio. In each variation of PALF tendency can be mapped, where the w/c ratio decreases then the strength of concrete will rise and the slump value is small. In the variation of concrete control, 0.04%, and 0.15% have the same curve trend while 0.09% tend that at w/c ratio 0.38 concrete strength is high, so the slump value is quite small. This agrees with previous works, that the presence of fiber in the concrete mixture will affect the slump value, further affecting the strength of the concrete [25]. Along with that, the increasing w/c ratio will increase the slump loss and resulting in a decrease in concrete strength [26]. Nonetheless, those results cannot be used for a very low w/c ratio, where there are restrictions on use, because concrete will lack water and shafts occur in concrete thus lowering the strength [27].

Figure 8 to 11 shows that the strength of concrete and the slump value to the w/c ratio have the same tendency in all PALF variations, where the relationship of concrete strength and cement ratio is expressed with the values $y = (-3872x^2) + (2752.7x) - 434.59$ and $y = 166.67x - 23,333$ for the value of concrete strength to slump values.
Figure 8. Relation between compressive strength, w/c ratio, and slump for control concrete.

Figure 9. Relation between compressive strength, w/c ratio, and slump for 0.04% PALF Concrete.

Figure 10. Relation between compressive strength, w/c ratio, and slump for 0.09% PALF Concrete.
4. Conclusion
The addition of fiber to high-strength of concrete affects the slump value, but with w/c ratio and PALF percentage amount reduces the effect of the reduction. Lack of water due to absorption by fiber can be overcome by adding water following the absorption capacity of water by fiber. The w/c low ratio increases concrete strength despite PALF presence in concrete. The presence of PALF in concrete helps in bridging microcrack on concrete thus increasing the compressive strength on concrete. The relationship between concrete strength and water ratio has the same tendency for concrete with all PALF variations.

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