The Flexural Capacity Study of High Strength Reinforced Concrete Beams Used Palm Oil Clinkers as Additives

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Abstract. The palm oil clinkers has a high silica content to use in high strength concrete mixtures as additives. In the study to replace silica fume used fly ash which is made from the palm clinkers and mashing then filtered with a No. #200 sieve. The study used a tested beam with 15 x 30 x 220 cm sized with concrete strength design (f’c) 60 MPa and (w/c) is 0.25. The main reinforced used 15.8 mm diameter with yield strength (fy) 446.34 MPa and shear reinforced used 11.9 mm diameter with yield strength (fy) 381.72 MPa. The compressive strength test at 28 days of 3 pieces of control specimens showed average value of 58.77 MPa. The maximum deflection in the middle of reinforced concrete beams is 31.8 mm at the maximum load 260.00 kN. The maximum deflection that happened is bigger than theoretical deflection with with two load points 17,126 mm. While the ductility produced by high quality reinforced concrete blocks with additives of palm oil clinkers is 2.313. Strain that occurs in tensile reinforcement and shear reinforcement under maximum loading conditions is 569,911 µm and 8,967 µm. The palm oil clinkers as a substitute for silica fume in high quality reinforced concrete is effectively used to increase concrete ductility.

Keywords: Reinforced Concrete Beams, Flexural Capacity, Additives, and Palm Oil Clinkers.

1. Introduction
High strength concrete is widely used in the constructions world because it has a fairly small porosity value so that a high density level is obtained. High strength concrete can be produced in several ways including applying high pressure, the use of aluminum cement and the method of addition or substitution. According to [1] Concrete which is classified as high strength concrete is concrete with strength between 40-80 MPa, or also according to [2] can be defined as high strength concrete that has compressive strength above 41.4 MPa. The use of additives (silica fume) and superplasticizer admixture as well as low of water cement ratio concrete values, will make the price of high strength concrete very expensive. The use of additives, both in form of mineral additives and chemical admixtures, is aimed to improve and increase the properties of each concrete material in conformity with the designated concrete properties. The mineral additives are used to enhance the strength and performance of concretes, while the chemical admixtures act for increasing the workability during concreting. The fly ash of Palm oil clinkers is a type of material that can be used as an additive. The utilization of the waste, especially in the Aceh area is still very limited, thus the use of palm oil clinkers fly ash as an additional substitute is still possible to be developed to produce high strength concrete at lower prices while maintaining the mechanical properties of high strength concrete in accordance with applicable standards.
This research was used palm oil clinkers fly ash for high strength reinforced concrete beam which passed the filter. No. # 200 as an additional ingredient to replace silica fume. Besides that, Viscocrete type Superplasticizer admixture is used as much as 2% by weight of cement. The specimens used are reinforced concrete beams with dimensions of 15 x 30 x 220 cm, compressive strength of concrete plans of 60 MPa and water cement ratio (w/c) of 0.25. The maximum diameter of aggregate used is 12 mm. The main reinforced screw with a diameter of 15.8 mm and shear reinforcement with a diameter of 11.9 mm with yield strength of 445.63 MPa and 381.97 MPa. The failure of concrete is brittle, in which the higher the strength the more brittle the concrete. High-strength concretes have a longer linear behavior range, but its post-peak region is smaller, and the stress drop faster (snap back). Therefore, one of the major parameter in determining the structural performance and ability is its ductility. Ductility is the ability of structure to deliver the post-yield deformation before collapse and may become the main parameter to control damage level. The behavior of brittle and ductile reinforced concrete member is shown in Figure 1. The structural element ductility (µ) can be calculated with the Equation (1), in which Δu is the ultimate strain of the flexural reinforcement and Δy is the yield strain of the reinforcement. [3]

\[
\mu = \frac{\Delta u}{\Delta y}
\] (1)

Figure 1. Load – Displacement Diagram of Brittle and Ductile Reinforced Concrete Member

This study aimed to analyze the flexural capacity of high strength reinforced concrete beams with palm oil clinkers fly ash as additive. The study obtain additional types of materials by utilizing palm oil clinkers effluents as additive substitutes for silica fume in improving the value of the high strength concrete flexural capacity.

2. Experimental/Methods

Material
The materials used in this research was Portland Cement type I, coarse aggregate with maximum diameter 12 mm, fine aggregate and that is Palm oil clinkers used as silica fume added and superplasticizer. The analysis physical of aggregate which are tested are sieve analysis, bulk density, specific gravity and absorption. While testing the analysis physical of cement is not carried out because it meets the requirements [4].

The palm oil clinkers material was obtained from one of the palm oil processing factories in the Nagan Raya region. The palm oil clinkers is the solid waste left over from the burning of oil palm fruit which is no longer utilized by the factory. According to the results of research [5] fiber burning waste and oil palm shells in the form of ash and clinkers which have useful elements to increase the strength of mortar. The use of palm oil clinkers fly ash as additives at a percentage of 15% can increase the strength of concrete, this shows that these additives can be used as a substitute for silica fume, as an alternative substitute for making high quality concrete. [6].
The results of previous studies on the physical analysis of palm oil clinkers and the chemical contents, data are obtained as in Table 1 and Table 2 [7].

**Table 1. The analysis physical of Palm Oil Clinkers**

| Analysis physical of Palm Oil Clinkers | Result |
|---------------------------------------|--------|
| Specific Gravity (SSD)                | 1.660  |
| Specific Gravity (OD)                 | 1.637  |
| Durability                            | 13.2%  |
| Absorption                            | 1.409% |
| Diameter                              | Passed = 19.1 mm, Restrained = 4.76 mm |

**Table 2. Composition of Palm Oil Clinkers Chemical**

| Chemical Elements                  | Percentage (%) |
|------------------------------------|----------------|
| Silica Dioxide (SiO$_2$)           | 38.128         |
| Aluminum Oxide (Al$_2$O$_3$)       | 10.302         |
| Iron Oxide (Fe$_2$O$_3$)           | 0.898          |
| Calcium Oxide (CaO)                | 3.926          |
| Magnesium Oxide (MgO)              | 3.649          |
| Missing Incandescent (LOI)         | 0.685          |

Superplasticizer is a chemical additive that is used to improve workability and reduce the amount of water mixing (high range water reducing admixture) [8].

**Mixed design, samples and test**

The method used in the planning of concrete mix composition in this study is the trial and error method, the quality of the concrete plan of 60 MPa, Cement Water Ratio (w/c) 0.25, palm shell ash as added material as much as 15% of the weight of cement and superplasticizer of 2% of the weight of cement. The test specimens used are 1 reinforced concrete beam with dimensions of 15 x 30 x 220 cm and concrete cylindrical control specimens (Ø = 15cm, T = 30 cm) of 3 pieces. Concrete testing is carried
out at 28 days with a pressure testing machine. The main reinforcement used is screw steel with a diameter of 15.8 mm with a yield stress ($f_y$) of 445.63 MPa and shear reinforcement is a steel screw diameter of 11.9 mm with a yield stress ($f_y$) of 381.97 MPa. Three LVDT (Linear Variable Displacement Transducer) were put at the beam to measure the deflection. Three strain gauges were installed on the reinforcements to measure the strain, each two at flexural tensile reinforcement and one at shear reinforcement (stirrups). Furthermore, one strain gauge to record the concrete deformation was placed at the maximum bending region of the beam (at midst of beam span). The beam test specimen set-up can be seen in Figure 3. The observed behaviors are cracks that occur namely initial cracks and crack patterns, deflection, steel and concrete strains, the maximum load carried by the beams and the pattern of destruction.

Figure 3. The specimen Set Up

3. Result and discussion

Concrete Compressive Strength
Based on the result of compressive tests on cylinder control specimen with a diameter of 15 cm and a length of 30 cm it is shown that high-strength concretes with Palm oil clinkers at the age of 28 days can be seen in Table 3. The average compressive strength values obtained in this study amounted to 58.77 MPa.

| Object | Dimension of Object (Cm) | Area (cm²) | Load (kg) | $f'_c$ (MPa) | Average of $f'_c$ (MPa) |
|--------|--------------------------|------------|-----------|--------------|-------------------------|
| BMT    | 29.85 15.05 177.78 110000 618.75 60.70 |
|        | 30.00 15.10 178.96 108000 603.49 59.20 58.77 |

Increase in compressive strength on the high-strength concretes containing palm oil clinkers as additive was mainly contributed by the environmentally friendly slag which constitute high cementitious materials in form of SiO2, Al2O3 and Fe2O3. The more finer particle size of the palm oil clinkers particles resulted in a denser concrete matrix with a lower porosity. Similarly, palm oil clinkers used as additive possesses a significant amount of such cementitious materials, in which a small part of cementitious materials could undergo wearing during concreting and could bind the Ca(OH)2 produced by primary hydration process to form extra Calcium Silicate Hydrate (C-S-H) which worked in enhancing the concrete compressive strength.

Reinforced Flexural Strength
The results of testing the tensile strength of steel used in this study can be seen in Table 4. The value of the main stress strength of 15.8 mm diameter screw steel of 445.63 MPa and 11.9 mm diameter steel screw shear reinforcement of 381.97 MPa.
**Table 4. Calculation of Tensile Test Results of Steel**

| No. | Diameter | Number of Object Test | Yield Tension | Yield Strain | Modulus Elasticity | Average of Modulus Elasticity |
|-----|----------|-----------------------|---------------|--------------|-------------------|------------------------------|
|     | mm       |                       | (kg/cm²)      | (%)          | (kg/cm²)          | (kg/cm²)                     |
| 1   | 11.90    | BU.1                  | 3947.04       | 0.195        | 2026723           | 2086732                      |
| 2   | 11.90    | BU.2                  | 3692.39       | 0.172        | 2146741           |                              |
| 3   | 15.80    | BU.3                  | 4710.99       | 0.248        | 1903429           |                              |
| 4   | 15.80    | BU.4                  | 4201.69       | 0.208        | 2024911           | 1964170                      |

Load and deflection
The relation of the load and deflection at the midst of beam span for high strength reinforced concrete beams carried out in this research program is given in Figure 4. From the load and deflection relationships shown in Figure 4 it can be analyzed that three main region occurs, which is, initial crack region, yield strength region and maximum load region. At initial crack region, high strength concrete beam underwent the first crack at a load of 6.76 ton with a deflection in LVDT 5 is 1.12 mm, LVDT 3 and 4 are 6.12 mm and 5.90 mm. In term of initial crack formation, it can be concluded that the use of palm oil clinkers as additives could enhance the load at first crack formation of high-strength reinforced concrete beams. At the transition region, the flexural reinforcement starts to yield. The amount of loads and deflections at the yield region which was recorded for high strength reinforced concrete beams at the load 24.52 ton and deflection 10.78 mm, 15.70 mm and 18.59 mm in LVDT 5, 3 and 4. Based on Figure 4 it also can be seen that the maximum deflection in LVDT 5 is 18.470 mm, LVDT 3 and LVDT 4 are 18.830 mm and 20.150 mm with a maximum load of 26.000 tons. These results indicate the maximum deflection that occurs is greater than the deflection calculated in theory to an ultimate load of 8.939 mm.

![Figure 4. Load and Deflection](image)

Load and strain of flexural tensile reinforcement
Comparison of the load and strain relationships of flexural tensile reinforcement for beams with palm oil clinkers as additives is shown in Figure. 5. Based on Figure 5 it can be seen that the melting strain at
tensile reinforcement is $105.90 \mu \varepsilon$ with a load of 26.00 tons. Based on the results, it can be clearly seen that the beam shows post-yield deformation better.

![Graph](image)

**Figure 5.** Load and Strain of Flexural Tensile Reinforcement

*Load and strain of shear reinforcement (stirrups)*

Relationships between the load and strain of shear reinforcement for all kinds of beams with palm oil clinkers as additives is shown in Figure 6. Based on Figure 6 it can be seen that the concrete strain is recorded at $3,460 \mu \varepsilon$ and $1,335.10 \mu \varepsilon$ with a load of 26.00 tons.

![Graph](image)

**Figure 6.** Load and Strain of Shear Reinforcement (Stirrups)

*Load and strain of concrete*

Comparison of the load and strain of concrete relationships for beam with palm oil clinkers is shown in Figure 7. Based on Figure 7 it can be seen that the concrete strain is recorded at $2,845 \mu \varepsilon$ at a load of 26.00 tons.
Comparison of capacity high strength concrete beams with theoretical and Laboratory. The capacity of high quality reinforced concrete beams is shown in Table 5, it can be concluded that for high quality concrete with the addition of additives can increase the flexural strength of high quality concrete.

Table 5. Comparison of capacity high strength concrete beams with theoretical and Laboratory

| Beam Specimen | Maximum Load (kN) | Flexural Moment (kN.m) |
|---------------|-------------------|------------------------|
|               | Pu Theory | Plab | Plab / Pu | Mn Theory | Mlab | Mlab / Mn |
| BMT           | 195.416    | 260  | 1.330     | 68.395    | 91,000 | 1,331     |

Crack and Fracture
Repeated the BMT beam testing with additive and substitution variations can be seen in Table 6 below. From Table 6 it can be concluded that the pattern of return that occurs is the bending taken.

Table 6  Laboratory Test Result

| Beam Uji Balok | Displacement | Strain | Concrete Strain | Displacement | Strain | Concrete Strain | Displacement | Strain | Concrete Strain |
|---------------|--------------|--------|-----------------|--------------|--------|-----------------|--------------|--------|-----------------|
|               | Tension      | Shear 1 | Shear 2         | Tension      | Shear 1 | Shear 2         | Tension      | Shear 1 | Shear 2         |
| BMT           | 1.210        | 0.570  | 10.020 | 0.570        | 1.120  | 0.570           | 10.020       | 0.570  | 1.120           |

The pattern of destruction that occurs in high quality reinforced concrete beams with added ingredients of palm shell ash in accordance with the planned pattern of destruction, namely bending failure. The initial crack occurred in the mid-beam region at a load of 6.76 tons. The number of cracks increases more along the stretch of the beam as the load increases. When the load reaches its maximum, one of the flexural cracks enlarges, in this condition the concrete has melted then followed by the melt of the flexural reinforcement. The loading conditions and destruction patterns that occur in the beam can be seen in Figure 8.
Before Loading (0%) First Crack

25% Load 50% Load

75% Load Maximum Load

Figure 8. Failure Pattern

Ductility

In Table 7 we can see the deflection that occurs in reinforced concrete beams due to the addition of loads under yield and ultimate conditions.

| No. | Beam Specimen | Yield condition | Ultimate condition | Ductility $\mu = \Delta u/\Delta y$ |
|-----|---------------|-----------------|-------------------|-----------------------------------|
|     |               | Load (P) Deflection ($\Delta y$) | Load (P) Deflection ($\Delta u$) |                                   |
|     |               | Ton Mm           | Ton Mm            |                                   |
| 1   | BMT           | 24,520 10,780    | 26,000 18,470     | 1.713                             |

Based on the table, BMT-CS with palm oil clinkers show values ductility is 1.713. In yield condition there was a load (P) of 24.520 tons and a deflection of 10.780 mm, then increased in an ultimate condition with a load value of 26.00 tons and a deflection value of 18.470 mm. Based on the results it could be obviously concluded that usage of palm oil clinkers as additives could increase the ductility of high-strength reinforced concrete beams, which has indeed a brittle behavior and characteristic.

4. Conclusions

1. BMT-CS beams with palm oil clinkers as additive have a flexural capacity value of 260 kN.
2. The maximum deflection occurred is 18,470 mm with maximum load (P) is 26.00 ton.
3. The crack pattern indicates that the beam has failed flexibly. It is proven by cracks occurred in flexible areas and almost no cracks occur in the support area. The first crack occurred at 6.76 ton, with deflection value is 1.12 mm.
4. Ductility in BMT-CS beams with palm oil clinker as additives obtained values ductility is 1.713

5. References

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