The Effect of Palm Shell as Coarse Aggregate Replacement on Self Compacting Concrete with Different Curing Methods

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Abstract. A type of concrete that has ability to compact itself without the aid of a vibrator or human labor known as Self-Compacting Concrete (SCC). This concrete is suitable for work on concrete structures need great effort to be compacted manually. The aim of this research is to study about the effect of replacing coarse aggregate using palm kernel shell waste. The variation of the shells used were 40%; 50% and 60% of the coarse aggregate volume. The utilization of palm shell waste was expected to reduce the use of natural resources as the primary material for concrete and utilize waste optimally. The tests consist of fresh and hardened properties. Fresh properties test was one of the mandatory requirements that must be perform on self-compacting concrete. There are several fresh properties test consisted of slump flow, T-50, J-Ring, V-Funnel and L-Box. Meanwhile, the hardened properties test was carried out in compressive strength and splitting tensile strength. Hardened properties testing was performed when the specimens were 3, 7, 28 and 56 days old. The curing process is carried out until the concrete was seven days old with a method consisting of sealed curing, moist curing, water curing, air curing and oven curing. The highest compressive strength and tensile strength for sealed curing, oven curing, moist curing and air curing methods were found in the palm shell variation of 60%, while in the water curing method the highest compressive strength was in the palm shell with a variation of 40% and the highest tensile strength was in the palm shell with 0% variation.

1. Introduction
Concrete is a construction material that popular with easily to make and widely used by people in the world. This material has several advantages such as excellent durability, high strength in compressive forces and low cost. Along with the technological developments, the need for concrete increases linearly with the complexity of the existing construction. Self-compacting concrete is suitable for constructions difficult to compaction manually during the casting process [1-2]. This type of concrete can self-compact under the force of gravity without a vibrator or human labor [3-4]. In the mid-1980s Japan first introduced self-compacting concrete, which is used to produce concrete with high performance and workability to avoid segregation due to imperfect compaction [5-6].

The application of environmental friendly materials has growth rapidly. The process of making concrete using natural materials continues to be of concern to environmental experts. Hence, it is necessary to replace materials sustainable, economical and friendly to the environment. The use of environmentally friendly materials in self-compacting concrete can be carried out using various methods such as replacement of cement, fine aggregate and coarse aggregate. Several studies have
discovered the partial replacement of cement with environmentally friendly waste materials such as bagasse ash [7-8], rice husk ash [9-10], palm oil ash [11-12] and kaolin [13] will be able to change the concrete properties characteristic. Furthermore, the waste materials as substitute for aggregate has also been found in various other studies consisting of the use of recycling concrete aggregate [14-15], Palm oil shell [16-17], and red brick masonry as fines aggregate [18].

This research utilized palm oil shell waste as partial replacement of coarse aggregate on self-compacting concrete. Oil palm shell was the great agricultural solid wastes that was found in Indonesia. Research in the last ten years has shown that oil palm shells can be used as a substitute for gravel to produce lightweight concrete. Moreover, silica fume added material was also used to strengthen the initial strength of the concrete. Several studies have been found regarding the effect of silica fume additive for the initial strength of concrete [19-20]. The use of Palm oil shell waste was 40%; 50% and 60% of the aggregate volume. Several fresh properties test and hardened properties test were performed in this study. Moreover, the fresh properties test consisted of slump flow, T-50, J-Ring, L-Box and V-Funnel. While, the compressive strength and splitting tensile strength were carried out for hardened properties. Curing was conducted using several methods consisting of sealed curing, moist curing, water curing, air curing and oven curing. All curing methods were carried out for seven days, then all specimens were transferred to air curing according to the test period, namely 3, 7, 28 and 56 days. Curing in the early strength of concrete is believed to help the hydration process become better. Several studies have explained the influence of the various curing method on the durability of concrete [21-23].

2. Experimental Program

2.1. Mix Proportions

The binder used in this study consisted of Ordinary Portland cement and silica fume, while other materials used were water, coarse aggregate, fine aggregate, palm kernel shell waste and superplasticizer for self-compacting concrete. Before using the aggregate, the properties were firstly checked. The mixed design used in this study refers to the research of Aggarwal et al in 2008 [24]. Replacement of coarse aggregate using palm kernel shells was as much as 40%; 50% and 60% of the total volume of coarse aggregate. Table 1 shows the results of calculating the mix proportion for 1m³. Based on ASTM C1240-03a [25], silica fume is a pozzolanic material mostly composed of amorphous silica and has a very fine texture. Silica fume has two effects due to its physical and chemical properties. The silica fume used in this study was Sika Fume with a 5% composition by weight of cement.

| Materials (Kg)                  | Variations             | NC (0% Palm Shell) | PS40 (40% Palm Shell) | PS50 (50% Palm Shell) | PS60 (60% Palm Shell) |
|---------------------------------|------------------------|--------------------|-----------------------|-----------------------|-----------------------|
| Portland Cement                 |                        | 485                | 485                   | 485                   | 485                   |
| Silica Fume                     |                        | 135                | 135                   | 135                   | 135                   |
| Water                           |                        | 253                | 253                   | 253                   | 253                   |
| Fine Aggregate                  |                        | 977                | 977                   | 977                   | 977                   |
| Coarse Aggregate (Rock)         |                        | 561                | 332.15                | 286.86                | 226.47                |
| Coarse Aggregate (Palm Shell)   |                        | -                  | 105.68                | 135.88                | 166.07                |
| Superplasticizer                |                        | 7.068              | 7.068                 | 7.068                 | 7.068                 |
| Total Weight of Aggregate       |                        | 1538               | 1414.83               | 1399.74               | 1369.54               |

2.2. Fresh Properties Test Method

The fresh properties test was carried out according to the standards for self-compacting concrete in the EFNACR 2002 and EFNARC 2005 [26-27]. The fresh properties test was conducted to determine the
flow rate, passing ability and fresh concrete viscosity. The fresh properties test consisted of slump flow to determine the concrete flow rate, while to determine the passing ability, both L-Box and J-ring tests were performed. V-Funnel and T-50 tests were carried out to determine the level of viscosity in fresh concrete. EFNARC 2002 and 2005 explain the conditions specified in each of the properties testing. Thereby the fresh concrete is categorized as self-compacting concrete. Table 2 shows the requirements determined by EFNARC, while Figure 1 is the test tool used to measure each fresh property.

**Table 2. Limitation of value for self-compacting concrete test method**

| Testing                  | Test limit          |
|--------------------------|---------------------|
| Slump flow (SF1)         | 520 mm - 700 mm     |
| Slump flow (SF2)         | 640 mm - 800 mm     |
| Slump flow (SF3)         | 740 mm - 900 mm     |
| T50                      | 2 - 5 seconds       |
| V-funnel (VF1)           | ≤ 10 seconds        |
| V-funnel (VF2)           | 7 – 27 seconds      |
| L-box (PA1)              | ≥ 0,75              |
| L-box (PA2)              | ≥ 0,75              |
| J-ring                   | 0 - 10 mm           |

**Figure 1.** (a) Slump Flow; (b) L-Box; (c) V-Funnel; (d) J-Ring

2.3. **Hardened Properties Test Method**

The hardened properties test in this study consisted of compressive strength and splitting tensile strength. The specimens in these two types of tests were cylindrical with a size of 75 mm and a height of 150 mm. The test was performed when the concrete was 3, 7 and 28 days old with curing variations
comprising of moist curing, sealed curing, water curing, air curing and oven curing (high temperature 70 ° C). Curing for each variation was conducted for seven days after the process of releasing the mold. After that, all specimens were cured using air curing. Concrete compressive strength tests were carried out according to the ASTM C39 standard [28] by giving axial pressure until the concrete was damaged. Meanwhile, the splitting tensile strength test refers to the ASTM C496 standard [29].

3. Results and Discussion

This section discusses three main parts of the research results: aggregate properties, fresh properties and hardened properties.

3.1. Aggregate Properties

Table 3 presents the testing results of the fine aggregate properties, revealing that the fine aggregate meets the standards for use as concrete material. The water absorption obtained is 1.97%, while the specific gravity obtained is 2.13. The value of specific gravity obtained is smaller than the fine aggregate in general, which is 2.50 while the absorption is 13.64% with a sludge content of 2%

Table 4 exhibits the results of the coarse aggregate properties. The coarse aggregate test using the Lost Angeles test covered moisture content, specific gravity, absorption and roughness values. This test was also carried out in combination with the palm shell mixture. The results disclosed that the moisture content and absorption increased if the number of palm shells used was higher, because they absorb water more efficiently than rock. Meanwhile, the resulting specific gravity value decreased, indicating that the higher the palm shell content used, the lighter the aggregate. Based on Los Angeles test, it show that the amount of palm oil shell affected to roughness content. High amount of palm oil shell as coarse aggregate substitute show lower roughness content. This results indicate that palm oil shell has high hardness level than rock.

| Test Item     | Unit | Fine Aggregate |
|---------------|------|----------------|
| Water Content | %    | 1.97           |
| Specific Gravity |     | 2.13           |
| Absorption   | %    | 13.64          |
| Mass Density | gr/cm³ | 1.51           |
| Mud Content  | %    | 2.00           |

3.2. Fresh Properties

Figure 2 shows the fresh properties test results on self compacting concrete (SCC) with a mixture of palm shells as a substitute for some coarse aggregate. The test results, revealed that the SCC concrete mixture met the 2002 EFNARC standard, except for the J-ring test. The required J-ring test was not allowed to exceed 10 mm, and the J-ring test did not meet the requirements do to the large size of coarse aggregate used in this study. Hence, the fresh concrete was unable to flow properly when passing through the reinforcement gap (passing ability). The size of the aggregate used should be 16 mm, but the oil palm shell size used in this study was more than 16 mm.
3.3. Hardened Properties

The test results depicted that all curing methods in concrete experience an increase in compressive strength with increasing age of the concrete as shown in Figure 3. Of the five curing methods, four showed that SCC concrete with a 60% palm shell mixture produced the highest compressive strength than other palm shell variations. It was because the value of the roughness content in the palm shell mixture was 60% smaller than other variations, while in the water curing method the highest compressive strength was found in palm shell variations with a content of 40%, as palm shell has a higher absorption capacity than rock. Therefore the lowest palm shell content resulted in the highest compressive strength. The curing method producing the highest compressive strength was in the oven curing method with 60% palm shell variation. Since the curing oven method could reduce the moisture content in the palm shell thereby increasing the compressive strength of the concrete. Conversely, the
curing method producing the lowest compressive strength was found on the moist curing method with a 50% palm shell variation.

Figure 3. Compressive Strength (a) Water curing; (b) Sealed Curing; (c) Oven Curing; (d) Moist Curing; (e) Air Curing
Figure 4 shows the splitting tensile strength test results on SCC concrete with a mixture of palm shell using five curing methods. The results, uncovered that all curing methods showed an increase in tensile strength with increasing age of the concrete. Similar to the results of the compressive strength test in the splitting tensile strength test, the sealed curing, oven curing, moist curing and air curing methods produced the highest tensile strength on the 60% palm shell variation, while in the water curing method the highest compressive strength was found in palm shell, with 0% variation. The curing method producing the highest tensile strength was the water curing method with 0% palm shell variation, while the curing method having the lowest tensile strength was the moist curing method with 40% shell variations.
4. Conclusions
The more palm shell content used, the smaller the specific gravity value. Furthermore, the addition of palm shell content also caused a smaller aggregate roughness content value.

The fresh properties test has met the 2002 EFNARC standard, except for the J-ring test that did not meet the EFNARC standard due to the large aggregate grain size.

The highest compressive strength and tensile strength for sealed curing, oven curing, moist curing and air curing methods were found in the palm shell variation of 60%, while in the water curing method the highest compressive strength was in the palm shell with a variation of 40% and the highest tensile strength was in the palm shell with 0% variation.

5. References

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