

# Study on the effect of pre-treatment of Oil Palm Shell (OPS) as coarse aggregate using hot water 50-°C and room temperature water 28-°C to lightweight concrete strength

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**Abstract.** With a rapidly growing population, the need for homes is increasing, which means the demand for housing material is also increasing in Indonesia. On the other hand, as the largest producer of palm oil in the world, Indonesia produces almost half of the world's palm oil inventories. Oil palm shells (OPS) are agricultural solid end products from palm oil manufacturing processes. In this research, the use of OPS waste as substitution materials for making concrete is investigated. In order to be used as structural building material, some mechanical properties of materials must achieve the requirements of the National Standard SNI. The general objective of this research is to understand the effect of the pre-treatment process on OPS aggregate on the mechanical behaviour of lightweight concrete. To do so, first, pre-treatment on the OPS is performed using hot water (50°C) and room temperature water (26-28°C). Second, by using the most effective mixed proportions from previous research in laboratory, pre-treated OPS is used to cast concrete. Third, some experimental tests are carried out to evaluate its mechanical properties, such as: concrete compressive strength, flexural strength and tensile strength (split test). Then, behaviour from both different treatments are compared and discussed. Finally, this research can determine which method gives better result for the application of OPS as biosource substituent material.

## 1 Introduction

Indonesia is listed as one of the largest producers of palm oil in the world, accounting for almost half of the world's palm oil inventories. Based on data from the Directorate General of Plantation, Indonesian Ministry of Agriculture, Indonesia's oil palm plantation area as of 2017 is estimated to reach 12.3 million hectares (Ha) [1]. The islands of Sumatra and Kalimantan are listed as the largest palm oil producing areas in Indonesia, resulting in many palm oil processing factories in those two islands. This large area of plantation and production increases the residual and/or by-product of Oil Palm Shell (OPS), for example, the remaining shell after oil extraction as a solid by product.

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On the other hand, as a developing country, along with the increasing demand for habitation in Indonesia, the need for concrete as the most favorable housing material is escalating. Nowadays, research to find alternative building materials to substitute natural aggregate and/or concrete ingredient is very attractive in the civil and material engineering domain. According to Yew et al. [3], oil palm shell can be used as coarse aggregate material (biosource material substituent). Therefore, as a possible substitute material in concrete mix proportions, a study on OPS becomes interesting.

Previous research in Indonesia and Malaysia shows interesting and promising results of OPS concrete, a term used to describe concrete material using oil palm shell as coarse aggregate. As it has a lightweight, OPS concrete can be a choice of the natural aggregate substituent for lightweight concrete [4-13]. Further research shows that OPS concrete can be used as ductile material [6] and moreover OPS can be used as aggregate for high strength lightweight concrete [8] and OPS with various additives [9-13].

OPS itself has different species, such as dura, tenera and pisfera OPS [1, 2]. In our laboratory, as the OPS comes from the island of Sumatra, specifically from Bengkulu Province, tenera is the species that is used in this experimental research. With reference to the lightweight concrete mixed design calculations of Indonesian National Standard [14] and standard specification for lightweight aggregates [15] for structural concrete, previous research in our laboratory [9-13] has determined the most optimum mix design proportion of OPS concrete using tenera. Table 1 below presents the concrete proportion according to [9-13].

**Table 1.** Concrete mixed calculation based on previous research [9-13].

Weight (kg/m <sup>3</sup> )				
Cement	Water	w/c	Oil Palm Shells	Sand
500	225	0.45	273	840

Pre-treatment process in the previous research is considered to be imprecise and unclear. Research in our laboratory [9-13] shows the needs to treat the oil palm shell obtained from the landfill as it has dirt on the outer surface and oily surfaces inside the shell. Fig. 1 below shows initial OPS sample at dry condition showing dusty surfaces. When it is soaked in water, bare hands can feel the oily surface of OPS.



**Fig. 1.** Oil palm shell (OPS) at initial dry condition (before pre-treatment).

In this paper, the authors are interested in the experimental works focusing on pre-treatment (washing) process of OPS coarse aggregate. There are two possibilities for this washing process, using hot water or room temperature (common) water. As stated before, the obtained OPS from palm oil landfill has oily surfaces. This condition may reduce material adhesion (connection between cement paste and shell), which decreases its strength under compression, tension, and flexural loading. Better adhesion between

concrete and aggregate may be obtained by increasing the irregular surface of aggregate and higher friction to cement paste. Therefore, using hot water seems realistic as pre-treatment on OPS for its ability in degreasing the shell. Higher mechanical response is expected to be obtained for the case of OPS pre-treated using hot water. In this experimental study, the authors chose 50°C of temperature as the hot water temperature condition. For common water, the temperature is between 26-28°C. In this work, results from [9-13] are used as a reference of mix design to determine the most effective concrete strength by water pre-treatment on OPS with hot and common water.

## 2 Methodology

In this section, there are two methodologies to be discussed, pre-treatment method to OPS and testing method to concrete samples.

### 2.1 Pre-treatment methodology

Hot and common water are the two parameters to be studied to determine which one is the best way to treat the OPS before mixing and casting. Details on the preparation of the OPS material are explained as follows.



**Fig. 2.** Condition of oil palm shell (OPS), (a) before pre-treatment, (b) pre-treatment with common (26°C) water, (c) pre-treatment with hot water (50°C).

The first step of pre-treatment is soaking the oil palm shell in hot water (50°C) or common water (26°C) for 20 minutes. At this step, dirt such as dust and mud attached on the shell will detach and float to the water level. In the second step, by using flowing common water for both types of pre-treatment, the dirt is removed from the water. For the third step, OPS is stirred, rubbed and brushed using bare hands. This step is performed during 4-5 cycles using flowing water depending on the condition of the shell. Slight abrasiveness (no more oily materials and impurities) on the shell indicates that we can continue to the next step.

As we use OPS as coarse aggregate, the authors choose 4.75 mm of sieve size (Sieve No. 4) to limit the size of OPS. In the fourth step, shells that are retained by sieve No. 4 and are passed from sieve No. 0.5” are separated and drained. Thus, the aggregate distribution for the OPS as coarse aggregate is larger than 4.75 mm and smaller than 12.5 mm. In the fifth step, the obtained aggregate is put in a container to be stored in a stove for 2x24 hours with 100°C of temperature. For the last step, after it dries, OPS is stored in a sack in a room temperature condition until it is used to mix with the cement paste. Fig. 2 shows the condition of the OPS before and after pre-treatment. It can be seen that there are no dusty surfaces on the pre-treated OPS.

## **2.2 Testing methodology**

Material testing on the OPS aggregate was already performed in previous works [9, 10]. There are three types of tests: concrete compressive, concrete flexural and concrete splitting test. For the first test, a small cylindrical specimen (20 cm of height and 10 cm of diameter) is used; for the flexural test, 15x15x60cm<sup>3</sup> of the beam is used; meanwhile, for the third test, a large cylindrical specimen (30 cm of height and 15 cm of diameter) is used.

### **2.2.1 Concrete compressive test**

Compressive strength test of concrete was carried out according to ASTM C39/C39M-18 Standard [16]. Test for compressive strength in this research is done by using a compression test machine with small cylinders at ages 7, 21, 28, and 56 days.

### **2.2.2 Concrete flexural test**

The flexural test is performed according to SNI 4431: 2011 [17]. This test method is to give two loads that work on a distance of 1/3 the length of the span (L). Loading is applied continuously on the beam until it is broken and unable to withstand the load. The age of flexural beam during the test is 28 days.

### **2.2.3 Concrete splitting test**

The direct splitting test is performed according to SNI 03-2491-2002 [18]. For this test, each sample was installed in the machine in a horizontal position with the special plate for splitting. The specimen was loaded slowly until it split and reached the maximum load.

## **3 Material characterisation**

In this study, the type of cement used is Portland composite cement (PCC). Portland composite cement is a hydraulic binder that is produced by grinding clinkers and certain amounts of inorganic materials such as gypsum, fly ash, slag, and limestone. The water used for concrete mixes is from natural groundwater in the laboratory. In the concrete mix, water holds an important role in triggering the chemical process of cement as an adhesive material and lubricates the aggregate to make it easier to do. As such, the quality of water used to mix concrete greatly affects the quality of the formed concrete. The water used in this study has been tested and compared with the existing standards according to the Indonesian Ministry of Health [19] concerning Drinking Water Quality Requirements. The water quality test results show that the water can be used for mixing the concrete.

The fine aggregates used in this study are natural sand from Ciawi, Bogor, West Java. Before using the sand, the first step is to eliminate dust and organic impurities. Moreover, for the coarse aggregates, in this case, they are palm shells originating from Bengkulu; the shells' dimensions range from 4.75-12.5 mm.

Because the absorption capacity of the OPS is very high, before the casting process, the OPS needs to be soaked for 24 hours to make a saturated condition. Then, it must be dried until surface saturated dry (SSF) condition is reached. The concrete mix design follows the formulation mentioned in Table 1 from previous research [9-13]. The physical properties for both OPS and natural sand are presented in Table 2 below.

**Table 2.** Physical properties of OPS and natural sand.

Property material	OPS	Sand
Max. Size (mm)	12.5	2.36
Specific Gravity	1.084	2.339
Bulk Density (compacted condition) (kg/dm <sup>3</sup> )	0.61	1.284
Absorption (%)	23.38	5.042
Fineness Modulus	6.23	2.362
Organic impurities (pallet number)	5	3
Mud content	-	7.20
Oil content mg/L	4007.56	

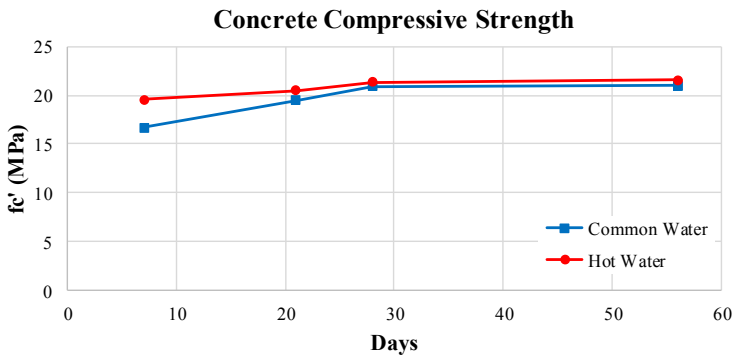
## 4 Results and discussions

### 4.1 Concrete compressive results

**Table 3.** Result of concrete compressive strength using hot and common water pre-treatment.

Sample code		Compressive strength [MPa]			
		7 days	21 days	28 days	56 days
Hot	1	19.99	21.64	21.20	21.67
	2	18.39	17.30	21.03	21.03
	3	20.08	20.07	21.64	23.40
	4	18.89	22.43	21.42	20.92
	5	20.52	20.98	21.53	20.61
	Average	19.57	20.49	21.36	21.52
Common	1	17.56	21.32	21.23	21.33
	2	16.56	17.55	21.40	19.78
	3	16.37	20.11	21.85	22.24
	4	15.45	20.99	19.81	20.61
	5	17.25	17.40	20.40	20.91
	Average	16.64	19.48	20.94	20.97

The results of concrete compressive tests are presented in Table 3. The flexure patterns of both types of concrete are the same. From Table 3 and Fig. 3, of the average of compressive strength test (concrete strength) pre-treatment with hot water has higher strength than the concrete strength with common water pre-treatment by 17.61% at seven days of age, 5.18% at age of 21 days, 2% at age of 28 days, and 2.62% at 56 days. This data shows that the hot water pre-treatment gives higher strength of concrete in the beginning or at early ages. In other words, in the hardening process, hot water treatment can help the concrete reach higher early strength. This condition may be advantageous for further application in larger structural elements, such as extraction from mold or formwork, the installation, and transportation of beam on the flexural bending machine, etc.

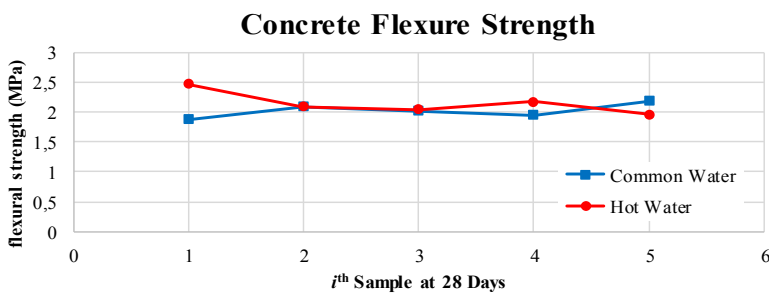


**Fig. 3.** Graphical representation of concrete compressive strength evolution in four different days using hot and common water pre-treatment.

#### 4.2 Concrete flexural tests results

**Table 4.** Result of concrete flexural test using hot and common water pre-treatment.

Sample code	Flexural strength (Mpa)					
	1	2	3	4	5	Average
Hot	2.47	2.09	2.04	2.18	1.96	2.15
Common	1.88	2.09	2.02	1.95	2.19	2.02



**Fig. 4.** Graphical representation of concrete flexural test for five samples at age of 28 days using hot and common water pre-treatment.

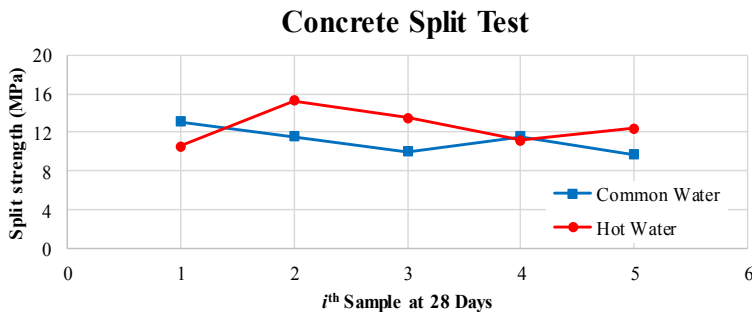
From Table 4, the result of flexural tests shown above, it can be seen that the average of flexural strength of concrete with hot water pre-treatment is higher than common water pre-treatment by 6.4%. From the graph of flexural strength test for both water pre-treatments on OPS, it shows that most of the samples from hot water pre-treatment have higher strength than common water pre-treatment. Only one sample of hot water pre-treatment has lower flexural strength.

### 4.3 Concrete splitting test results

The direct splitting test in this study was carried out on the large cylinders at 28 days of age with 15 cm of diameter and 30 cm of height. From the result of the concrete splitting test, hot water pre-treatment has higher strength on average than common water pre-treatment by 12.5%. The most different result of direct splitting strength between both methods is at sample 2. The method of using hot water pre-treatment at sample 2 compared with the other method shows 32.3% difference of strength.

**Table 5.** Result of concrete split test using hot and common water pre-treatment.

Sample code	Split strength (kg/cm <sup>2</sup> )					
	1	2	3	4	5	Average
Hot	10.55	15.29	13.49	11.20	12.37	12.58
Common	13.13	11.56	9.98	11.56	9.65	11.18



**Fig. 5.** Graphical representation of concrete split test for five samples at age of 28 days using hot and common water pre-treatment.

## 5 Conclusions

Based on the previous research in the Laboratory of Structure and Material Universitas Indonesia, the needs of pre-treatment on oil palm shells (OPS) emerged. In this paper, the importance of the pre-treatment process on OPS is studied by performing an experimental series of works. Hot water (50°C) and common water (26-28°C) are the two parameters chosen to be investigated. Three experimental tests (compressive, flexural and split tests) prove the significance of these two different treatments.

The concrete compressive test shows that the early strength of lightweight concrete with hot water pre-treatment on OPS is higher than the common water one. Hot pre-treatment results in 17.61% higher concrete strength at seven days of age. Moreover, at age 28 and 56 days, where concrete strength is normally stabilized, the hot water pre-treated sample has slightly larger strength than the one from common water, 2.0%, and 2.62%, respectively. In

general, hot water treatment gives higher strength of concrete, especially at an early age. Higher early strength may be advantageous for further application.

For concrete flexural test (four-point flexural loading), hot water pre-treatment gives higher flexural strength than common water pre-treatment by 6.4%. The average of flexural strength of pre-treated hot water is 2.15 MPa. Flexural test using a four-point bending test is used to investigate the first crack appearance at the bottom of the beam (concrete fiber under tension) in a pure flexure condition. The first crack in hot water pre-treated OPS concrete is higher than the common water one. In other words, hot water OPS has greater resistance to withstand the first crack under pure bending condition. The last test, concrete splitting test using hot water pre-treatment, has higher strength than the common water pre-treatment on OPS as the coarse aggregate by 12.52%.

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