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The Effect of Variations of Palm Oil Shell Waste and Fly Ash on The Compression Strength of Concrete

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Abstract

Concrete is a composite building material made from a combination of coarse aggregate, fine aggregate, and cement paste, which is very often used in Indonesia's building and construction sector. The increase in the use of concrete causes the number of available resources to decrease so one alternative that can be used to overcome this is to utilize the results of industrial waste as a substitute for concrete constituents. This study aimed to determine the composition and results of the compressive strength of concrete using substitution materials in the form of oil palm shells and fly ash. The percentage variations used are 0%, 3%, 6%, and 9% for oil palm shells and 5% for fly ash in each mixed plan with a design concrete quality of K-200. The number of test objects is nine cubes per mixed variation with a test age of 7 days, 14 days and 28 days, such as for village roads, ground floors and column foundations.

Introduction

Concrete is a vital building material consisting of cement, coarse aggregate, fine aggregate, and water. Concrete can be easily shaped according to the construction needs, capable of carrying heavy loads, is resistant to high temperatures, low maintenance costs and others. The strength of concrete is highly dependent on the composition of each material forming and processing methods. It has been successfully made lightweight concrete with palm shell substitution. From the research that has been done, it is concluded that there is an effect of substitution of palm shells on the compressive strength value, namely the inverse relationship, the smaller the percentage of addition of palm shells, the greater the value of the compressive strength of concrete and vice versa. Palm shell substitution also affects the weight of concrete. The greater the percentage of palm shell substitution, the lighter the weight of the concrete and vice versa (Berli, 2019).

Kotabaru Regency has a large amount of palm shell waste, so it is necessary to find a solution to utilize it. One of them is as a substitute for fine aggregate in the manufacture of concrete. That is what underlies me to do this research because palm shells are industrial waste from the palm oil mill, which is later expected to be concrete that has good quality but does not reduce the value of concrete strength, and can reduce the negative impact of palm shell waste on the environment (P et al., 2019).

The palm oil shell is the hard part found in oil palm fruit, which serves to protect the kernel contents of the oil palm fruit. The shell is almost the same as the coconut shell, which is often found daily, however, the waste produced has not yet been utilized optimally and this can be seen from the location of the accumulation of waste around the factory location, which is getting higher along with the increase in oil production from palm oil mills. (Haniza & Hamidi, 2017).

Fly ash is a by-product of the Steam Power Plant (PLTU) industry that uses coal as fuel, in the form of light, round, non-porous and pozzolanic fine granules. The addition of fly ash to the concrete mixture is pozzolanic, so it can be a good mineral additive for concrete. Pozzolan is a material containing silica or silica and aluminum that chemically reacts with calcium hydroxide at ordinary temperatures to form cementitious (binding) compounds.

Fly ash is a material that is gray, has a fine grain size, and is obtained from coal combustion residues. According to the Government Regulation of the Republic of Indonesia No. 18 of 1999 concerning Management of Hazardous and Toxic Waste, states that fly ash is categorized as a B3 material. According to research that has been done, fly ash is proven to increase the strength of concrete. The rapid development of road pavement will require more materials. With this, it can be studied further by composing or partially replacing portland cement with fly ash. By using Fly ash, it is hoped that this coal waste can be put to good use.

Fly ash is part of the rest of the coal combustion in the steam power plant boiler in the form of fine particles and is pozzoland, meaning that the fly ash can react with lime at room temperature (24°C - 27°C) in the presence of a medium water to form binding compounds. With these pozzolanic properties, fly ash can be used for various building purposes. Ash is inorganic material left over from coal combustion and is formed from changes in mineral materials due to the combustion process. In coal combustion in power plants, two types of ash are formed: fly ash and bottom ash. The ash particles carried by the exhaust gases are called fly ash, fly ash is captured with an electric precipitator before being discharged into the air through the chimney. Pozzolan can be used as an additive or as a partial replacement for portland cement (Purnamasari et al., 2022).

This study tries to take advantage of the natural conditions of Indonesia and the use of local materials whose additional material is in the form of palm oil shells from PT. Hasnur Citra Terpadu and fly ash from the Asam-asam power plant. This research was conducted to obtain a new alternative in concrete technology, using crushed stone and cement as efficiently as possible, namely by replacing some of the coarse aggregates with oil palm shells and also replacing some of the cement with fly ash—strength of the design concrete. Based on the things above, the objectives of this research are as follows: knowing the results of the compressive strength of concrete using palm oil shell waste and fly ash.

Palm Oil Shell

The oil palm shell or often called the palm shell (Figure 1) is the hardest part of the oil palm fruit, which serves to protect the contents of the oil palm fruit. It is hoped that palm oil shells can be used as a substitute for some coarse aggregate in concrete mixtures by having a hard texture like gravel. The use of palm kernel shells in the concrete mix can reduce the self-weight of the concrete, and save the use of aggregates and the necessary costs. (Syarifudin et al., 2021)

Figure 1. Oil Palm Shell

Mineral Additives (Additive)

Mineral added materials are more widely used to improve the compressive strength of concrete. Adding these mineral additives can help reduce the use of cement in concrete, reduce temperatures due to hydration reactions and reduce or increase the workability of concrete. As for mineral added materials, one of which is fly ash (fly ash), fly ash (fly ash) is a solid waste from coal combustion which is classified as B3 waste because it contains metal oxides which will undergo a natural reaction which will eventually pollute the environment.
In SNI 2460:2014 the specification of fly ash as an additional material for concrete mixtures states that there are three classes of fly ash, namely:

1. Class F fly ash, is fly ash produced from burning coal, anthracite type at a temperature of 1560°C.
2. Class N fly ash is the result of the calcination of natural pozzolans such as diatonic soil, shale (shale), tuft, and pumice.
3. Class C fly ash is fly ash produced from limit combustion of coal with a carbon content of ± 60%. Fly ash has pozzolanic and cement-like properties with lime content above 10%.

In SNI 2460:2014, the requirements for chemical content in the fly ash class can also be seen in Table 1:

Table 1. Chemical content requirements of Fly Ash

Description	Fly Ash Class		
	N	F	C
SiO_2 +Al_2O_3 +Fe_{23}, min %	70	70	50
SO_3, max %	4	5	5
Moisture Content, max %	3	3	3
Glow, max %	10	6^A	6

Source: SNI 2460 : 2014 Specifications of Coal Fly Ash and Raw or calcined Natural Pozzolan used in Concrete

Method

Research Procedure

Preparation and Ingredients

Preparation and supply of materials include the preparation and supply of materials. All the materials that will be used are prepared in advance so that this research runs smoothly.

1. Cement type I (PCC) uses Tiga Roda brand cement.
2. Fly Ash as a substitute Some of the cement used comes from the PLTU Asam-asam.
3. Palm oil shells as a substitute. Some of the coarse aggregate used comes from PT. INTEGRATED IMAGE HASNUR.
4. Coarse aggregate used is cotton stone.
5. The fine aggregate used is barito sand
6. The water is from the Structure and Materials Laboratory, Civil Engineering, Banjarmasin State Polytechnic.

Material and Equipment Inspection

In this study an examination of the equipment and materials to be used. This research was conducted to test cement, fly ash, oil palm shell, coarse aggregate, and fine aggregate. It aims to determine the properties and characteristics of cement, fly ash, palm shells, coarse aggregate and fine aggregate used.

1. Testing of cement and fly ash, as follows:
   a. Fineness test of cement and fly ash (SNI 15-2530-1991).
   Materials needed are: 1) filter No. 100 and No. 200 according to ASTM standard, 2) analytical balance weighing 50 grams up to 10 mg, and 3) a brush with the right size of handle and bristles for this need.
   b. Testing the specific gravity of cement and fly ash (SNI 15-2531-1991).
   Materials used are: 1) Le Chatelier bottle/pycnometer, 2) Soaking Tub, 3) Cup, and 4) scale
   c. Testing the normal consistency of cement and fly ash (SNI 03-6826-2002).
   It requires balance sheet, 200 ml measuring cup, a set of vicat tools consisting of, vicat tools and konik ring, flattening spoon, and mixer.
   d. Testing of cement and fly ash binding time (SNI 03-6827-2002).
   The testing needs a scale, 200 ml cup, a vicat tool set consists of a vicat tool and a Konik ring, stopwatch, leveling spoon, and mixer
2. Testing of coarse aggregate and oil palm shells, as follows:
   a. Specific gravity and absorption testing (SNI 1969-2008).
   The materials needed are wire basket, suitable capacity and shape for inspection, container which is equipped with pipes so that the water level is always constant, scales with a capacity of 5 kg are equipped with a basket hanging device, and the oven, which is equipped with a temperature of $110 \pm {}^{o}$
   b. Filter analysis test (SNI 03-1968-1990).
   It needs scales, a set of filters; 19.l mm (3/4");12.5 mm (1/2"); 9.5 mm (3/8" ; no.4 ; no.8 ; no.16 ; no.30 ; no.50 ; no.80 ; no.200 (ASTM standard), separator, filter shaker machine, tray, brushes, brass brushes, spoons and other tools.
   c. Weight test (SNI 03-1973-1990).
   It needs scales, tray with a large enough capacity, compactor wand diameter 15 mm, length 60 cm with rounded tip preferably made of stainless steel, leveling ruler, and sufficiently rigid steel cylindrical container with tool holder.

d. Coarse aggregate abrasion test (SNI-2417-2008).
It needs the machine consists of a closed steel cylinder , a hollow cylinder for inserting the test object . The manhole cover is tightly closed so that the inner surface of the cylinder is not disturbed; filter no. 12; and steel ball.

e. Sludge content test (SNI 03-4142-1996).
The equipment used are filter no. 200, test object washing container, oven, equipped with a temperature control of 110, scales, and tray.

f. Water content testing (SNI 1971-2011).
It needs scales, oven, equipped with 110º temperature control, and stainless metal tray.

3. Fine aggregate testing, as follows:

a. Specific gravity and absorption testing (SNI 1969-2008).
The testing requires scales, pycnometer with a capacity of 500 ml, beheaded cone, pounding rod, oven at 110º temperature control, and tray.

b. Filter analysis test (SNI 03-1968-1990)
Tools needed are scales, a set of filters; 19.l mm (3/4");12.5 mm (1/2"); 9.5 mm (3/8") no.4 ; no.8 ; no.16 ; no.30 ; no.50 ; no.80 ; no.200 (ASTM standard), oven at 110º temperature control, separator, filter shaker machine, tray, brushes, brass brushes, spoons and other tools.

c. Weight test (SNI 03-1973-1990).
The test needs scales, tray with a large enough capacity, compactor stick with diameter l5 mm and length 60 cm with rounded tip best made of stainless steel, leveling ruler, sufficiently rigid steel cylindrical container with tool holder.

d. Sludge content test (SNI 03-4142-1996).
It needs filter no. 12, test object washing container, oven at 110º temperature control, scales, and tray.

e. Water content testing (SNI 1971-2011).
The test needs scales, oven at 110º temperature control, and stainless steel tray for drying test objects.

4. Procedure for mixing concrete casting (SNI 03-3976-1995)
The equipment used must meet the following requirements:

- Equipment for dosing, mixing and transporting must be in good condition and clean
- The mixer (molen) must be at the speed recommended by the manufacturer
- The means of transportation used from the place of mixing
- The compactor used must be adapted to the shape and type of work

The steps for mixing concrete are as follows:

- Measure the ingredients used for making concrete
- Enter the ingredients while the molen machine is spinning
- Continue stirring at least 11/2 until a uniform mixture is obtained
- Perform a slump check no later than 5 minutes after mixing and take fresh concrete for the manufacture of test specimens if needed no later than 15 minutes after mixing
- Clean the cylinder or cube that will be filled with mortar from dirt or hardened concrete powder then apply enough oil to the side of the cylinder or cube to make it easy to remove.
- Remove fresh concrete from the mixer machine and then pour it into cylinders or cubes with equipment either manually or mechanically.
- Compact the concrete with a compactor stick with rounded ends preferably made of stainless steel
- Treat the compacted concrete to keep it moist.

5. Procedure for concrete slump test (SNI 1972-2008)
   Equipment :
   - Test equipment in the form of molds made of non-stick metal. The thickness of the metal should not be less than 1.5 mm and the mold must be in the form of a truncated cone with a base diameter of 203 mm, an upper diameter of 102 mm, and a height of 305 mm.

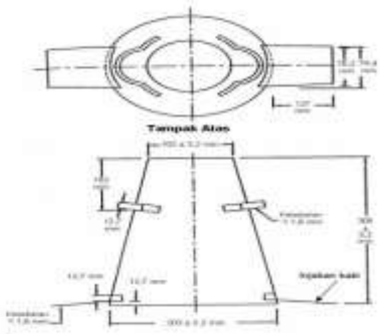

Figure 2. Molds for Slump Test

(Source: SNI 1972-2008)

   - The stabbing rod is a straight steel rod that has one half-spherical shape, circular cross-section with a diameter of 16 mm and a length of approximately 600 mm.

   Slump test working steps:
   - Wet the mold and place it on a flat, damp, non-absorbent and stiff surface.
   - Compact each layer with 25 stitches using a compactor stick. Spread the stitches evenly.
   - In filling and compacting the top layer, add more concrete to the top of the mold before compaction begins. After the top layer has been compacted, smooth the surface of the concrete on the top of the mold by rolling an awl over it. Immediately remove the mold from the concrete by lifting it in a vertical direction carefully.
   - After the concrete shows settlement on the surface, immediately measure the slump by determining the vertical difference between the top of the mold and the center of the top surface of the concrete.

Concrete Mix Plan

In this study, planning a concrete mix using 4 variations of Filler Materials 0%, 3%, 6%, 9% and Fly Ash 5% in each mixture that uses palm kernel shell waste with K-200 quality, K-200 quality concrete means that it is a concrete construction that can receive a compressive load from a compressive strength machine of 200 Kg/cm2 . The use of concrete with the quality of K-200 is intended for non-structural or concrete construction projects that do not require special iron reinforcement. This method includes general requirements and technical requirements for planning the proportion of concrete mixture to be used as a reference for planners and implementers in planning the proportion of concrete mixture to produce concrete quality according to the plan by using a reference (SNI 03-2834-2000).

Test Object Manufacturing and Maintenance
In the manufacture of this test object using a cube mold 15 x 15 cm. It is planned that in this study the number of specimens for each variation is 9 pieces. This method includes the procedure for making and maintaining a cube test object from a representative sample of concrete for a construction project using a reference (SNI 2493:2011) .

Test Object Test
This testing stage is where the compressive strength of concrete is tested at the age of 7,14 and 28 days. Calculated after the first day of casting. Testing the compressive strength of concrete (SNI 1974-2011). The compressive strength of concrete is a test of the magnitude of the load per unit area, which causes the concrete test object to crumble when pressed/loaded with a certain compressive force produced by the press machine.

Results and Discussion

Palm Oil Shell Test Results

The oil palm shell used in this study is a partial substitute for coarse aggregate from PT. Hasnur Integrated Image. Tests carried out for partial replacement of coarse aggregate are testing specific gravity, sieve analysis, bulk density, hardness, abrasion, silt content, and water content. The results of the coarse aggregate test can be seen below.

Table 1. Results of Inspection of Oil Palm Shells for Concrete Mixes Origin of Material: Palm Oil Shell (PT. Hasnur Citra Terpadu)

No	Kinds of Inspection		Coarse Aggregate		Specification SII 0052-80
			Standard / Reference	Results	
1	Specific gravity		SNI 1970 : 2008		Min 2.5%
	Bulk Density			1,100	
	SSD Density			1.310	
	Apparent Density			1.393	
	Absorption	%		19,110	Max 3%
2	Aggregate Grading Arrangement		SNI 03-1973-1990		
	1 1/2" (38.1mm)			100	
	3/4" (19.1mm)			82.34	
	3/8" (9.52mm)			13.44	
	No.4 (4.76mm)			0.42	
	No.8 (2.38mm)			0	
	No.16 (1.19mm)			0	
	No.30 (0.59mm)			0	
	No.50 (0.28mm)			0	
	No.100 (0.15mm)			0	
	Fineness Modulus	%		7.04	6.0% – 7.1%
3	Fill Weight	Kg/lt	SNI 03-4804-1998		
	Weight of loose aggregate			0.659	
	Density of solid aggregate with Puncture			0.732	
	Density of solid aggregate with Wobble			0.696	
4	Hardness/Wear:				
	Los Angeles	%	SNI 2417-2008	3,296	< 27%
5	Sludge levels	%	SNI 03-4142-1996	2,637	1%

6	Moisture Check	%	SNI 03-1971-1990	3,969	-

(Source: Laboratory Test Results, 2022)

From the test results, it can be concluded that palm kernel shell waste can be categorized as lightweight aggregate because it has a specific gravity of more than 3% and has high absorption, while the sludge content has a value of 2.637 above the maximum limit, it must be washed first.

Composition of Concrete Mixture (*Mix Design*)

In planning the concrete mix (*mix design) according to* SNI 03-2834-2000 the materials used are water, three-wheel cement, *fly ash* from the Asam-asam power plant, fine aggregate of barito sand, coarse aggregate of cotton crushed stone , the proportion of concrete mix with K-200 quality varies starting from 0%, 3% CKS, 6 % CKS, 9% CKS *and 5% Fly Ash* in each mixture that uses palm kernel shell waste . The results of the concrete mix mixture are in Table 2 to

Table 2. Proportion of Concrete Mixture 0%

Mixed Proportion	Cement (Kg)	Fine (Kg)	Water (Kg)	Aggregate Surface Dry Saturated Condition (kg) Coarse Aggregate 1 – 2
Each m3	380	722	190	1083
Test object (9 cubes)	11.54	21.93	5.77	32.90

(Source: Laboratory Test Results of Banjarmasin State Polytechnic , 2022)

Table 3. Proportion of Concrete Mixture with 3% CKS and 5% *Fly Ash*

Mixed Proportion	Cement (kg)	FA (kg)	Fine (Kg)	Water (kg/lt)	CKS (Kg)	Aggregate Surface Dry Saturated Condition (kg) Coarse Aggregate 1 – 2
Every m	361	19	722	190	32.5	1050.5
Test Objects (9 cubes)	10.97	0.58	21.93	5.77	0.99	31.91

(Source: Laboratory Test Results of Banjarmasin State Polytechnic , 2022)

Table 4. Proportion of Concrete Mixture with 6% CKS and 5% *Fly Ash*

Mixed Proportion	Cement (kg)	FA (kg)	Fine (Kg)	Water (kg/lt)	CKS (Kg)	Aggregate Surface Dry Saturated Condition (kg) Coarse Aggregate 1 – 2
Every m	361	19	722	190	65	1018

Test Objects (9 cubes)	10.97	0.58	21.93	5.77	1.97	30.92

(Source: Laboratory Test Results of Banjarmasin State Polytechnic , 2022)

Table 5. Proportion of Concrete Mixture with 9% CKS and 5% *Fly Ash*

Mixed Proportion	Ceme nt (kg)	FA (kg)	Fine (Kg)	Water (kg/lt)	CKS (Kg)	Aggregate Surface Dry Saturated Condition (kg) Coarse Aggregate 1 – 2
Every m	361	19	722	190	97.5	985.5
Test Objects (9 cubes)	10.97	0.58	21.93	5.77	2.96	29.94

(Source: Laboratory Test Results, 2022)

For a more complete description of the results of the concrete mix mix about concrete mix planning calculations (*mix design) according* to SNI 03-2834-2000 .

Concrete Compressive Strength Test Results

The results of testing the compressive strength of concrete in this study 1 variation of the quality of concrete there are 9 cube specimens and divided into 3 ages, namely 7, 14 and 28 days. In testing the compressive strength of this concrete can be seen in Table 6.

Table 6. Test Results for K-200 . Concrete Compressive Strength

No	Test Object	Strong Press		
		Age 7 Days	14 Days Age	Age 28 Days
1	Normal Concrete 0%	250.56	264.65	224.00
2		2 92.65	222.22	234.67
3		270.77	191.92	226.67
	Average	**271.23**	**226.26**	**228.44**
1	3% CKS Variation Concrete + *Fly Ash* 5 %	284.44	202.02	248.00
2		273.50	201.01	231.11
3		231.11	271.72	222.22
	Average	**263.02**	**224.92**	**233.78**
1	Variation of Concrete CKS 6% + *Fly Ash 5%* %	184.62	171.72	186.67
2		229.74	161.62	201.78
3		242.05	156.57	194.67
	Average	**218,80**	**163.30**	**194.37**
1	Variation of Concrete CKS 9% + *Fly Ash 5%* %	194.19	131.31	182.22
2		180.51	151.52	138.67
3		180.51	141.41	144.89

	Average	185.70	141.41	155.26

(Source : Laboratory Test Results, 2022)

Calculation of Standard Deviation of Concrete Compressive Strength

From the results of testing the compressive strength of concrete of varying quality, the next step is the calculation of the standard deviation (S), average compressive strength ($\underline{x}$), and characteristic compressive strength (K) which can be seen in figure 3.

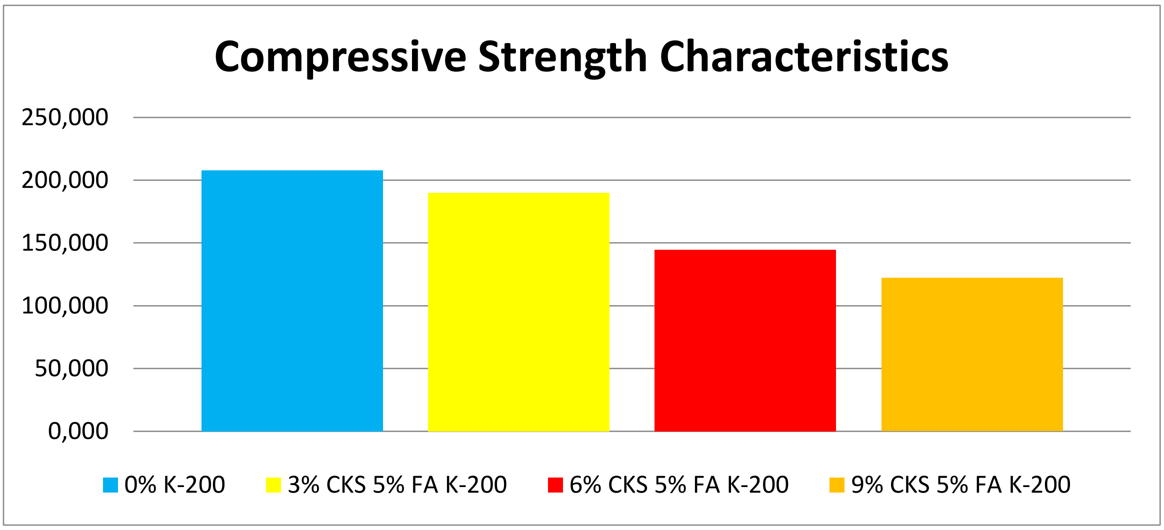

Figure 3. Graph of Compressive Strength Characteristics of Concrete

Conclusion

The results of the characteristic compressive strength for concrete with 0% palm shell and *fly ash* obtained are 207,850 kg/cm ^{2} , concrete with 3% palm shell and 5% *fly ash* obtained by 190,018,286 kg/cm ^{2} , concrete with 6% palm shell and 5% *fly ash* obtained by 144,678 kg/cm ^{2} , and concrete with 9% oil palm shell and 5% *fly ash* obtained by 122,011 kg/cm ^{2} . From the four variations above, the compressive strength according to the K-200 plan is obtained in 0% palm shell concrete and *fly ash,* while in concrete with 3% palm shell variations and 5 *fly ash*, concrete with 6% palm shell variations and 5 *fly ash* . % and concrete with 9% oil palm shell variation and 5% *fly ash* did not reach the design quality of K-200 but the mixture of 3% oil palm shell and 5 *fly ash* was almost close to the design concrete quality. From these results, concrete using palm oil shells and *fly ash* can be categorized as class 1 concrete quality and can be used for non-structural buildings, such as for village roads, ground floors and column foundations.

Recommendations

Further research is needed on the characteristic content of oil palm shells and fly ash. The need for additional specimens for concrete to make more so that the comparison of compressive strength is more effective, For future research, it is recommended to use a lower quality plan than this research.

Acknowledgements or Notes

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