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Young Coconut Husk Ash as Partial Cement Replacement in Masonry Application

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Abstract

To address the increasing amount of municipal and urban wastes brought about by tough and heavy biodegradable wastes from popular consumption of young coconut water and meat in municipal and urban centers in the country, a study is conducted to utilize these waste materials into ash to substitute cement for concrete production. Wasted young coconut husks with their shells were collected and burnt at 600 ^{0}C to produce ashes that were tested for its physical and chemical characteristics. The ash was mixed with fine aggregates and water to six design mixtures using Young coconut husk ash (YCHA) at 20%, 40%, 60% 80% and 100% as partial replacement of ordinary Portland cement. Specimens without YCHA (0%) are also prepared to serve as the control specimens of this study. The study provided an encouraging implication on the use of young coconut husk ash as partial cement replacement to up to 60% by weight in which mortar produced are acceptable for certain type of construction applications.

Keywords*:* young coconut husk ash, cement substitute, partial cement replacement

1. Introduction

Concrete is a heterogeneous composite material that consists of aggregate (sand, gravel and a binding medium made of Portland cement and water. Concrete is one of the most versatile construction materials in the world wherein about 10, 000 m^3 (or 4.2 billion tonnes) of concrete is being used every year. There are several reasons on the popular use of concrete which include: reliability, strong structure, fire resistant, resistant to water and environmental extremes and sound insulating structure (Thomas Concrete Group, 2015).

Several studies had been successful to partially replace cement with local available materials such as agricultural wastes including rice hull ash (Obilade, 2012) ; peanut shell ash (Nimitsyungskol and Daladar, 1995) ; corn cobs ash (Olafusi and Olutoge, 2012); saw dust ash (Raheem and Sulaiman, 2012; Obilade, 2014); mature coconut shell ash (Nimityongskol and Daladar, 1995; Oyelade, 2011; Aho and Utsev, 2008; Utsev and Taku, 2012) ; mature coconut fiber ash (Sen and Chandak, 2015; Kumar *et al.*, 2015; Okere, 2013); Palm oil fuel ash (Tangchirapat *et al.*, 2009); bamboo leaf ash(Dwivedi, *et al.*, 2006; Aprianti, *et al.*, 2015); and industrial by products such as fly ash (Thomas, 2007; Obla, 2008; Kumar *et al.*, 2015); and slags (Slag Cement Association, 2002) .

The Philippines is blessed with abundant number of coconut trees which is even considered as the supplier of world market for coconut oil and copra meal (Zafar, 2014). Waste product from mature coconut has been managed considerably because there is market for the coconut strong fibers for various engineering applications such as coir mattresses, car components, including coconut husk ash and hard shell ash for cement replacement. Coconut shells are also considered for its charcoal uses. Currently, there is no problem in dealing with wastes from the mature coconut husks and hard shells.

With the advent of people learning the benefits of consuming young coconut as one of the most beneficial natural health drink, the young coconut (locally called *buko*) has become popular commodity in places where marketability of these product can be obtained (see Fig. 1). This is where the problem of waste management occurs because young coconut husks with shells are considered of “no economic value” after removing the water and the tender meat. The waste material generated from the young coconut husk is quite heavy to handle aside from being bulky when accumulated in garbage disposal areas. Although considered a biodegradable material, young coconut husks takes a long time to decompose thereby creating a problem of waste disposal management (see Fig. 2).

Figure 1. Refreshing Young Coconut Drink

Figure 2. The wastes generated after consuming young coconut in urban centers

In order to address the pressing issues of waste management of this no-economic value material from young coconut husks with shells, an experimental investigation was conducted to understand the characteristics of this waste material and its suitability for concrete applications.

This study presents the suitability of using young coconut husk ash as partial cement replacement. This work investigates the compressive strength of mortar specimens at different design mixtures and at different stages of curing.

2. Methodology

Young coconut husks with shells were collected from different garbage locations in Cagayan de Oro City. The young coconut husk materials were subjected to open air drying for about 2-3 weeks to facilitate the burning process for ash collection. Open burning was performed in a drum at about 600 ^{0}C. After cooling, the ashes were collected and subjected for chemical testing, fineness test and specific gravity determination.

The ashes were subjected to the chemical test for magnesium oxide and calcium oxide contents to determine whether YCHA has pozzolan characteristics. Time setting of cement blended with YCHA were also tested using the standard test methods for time setting of hydraulic cement by Vicat needle (ASTM C191).

Cement used in this study is Type 1 ordinary Portland cement from LaFarge. Fine aggregates was obtained from local supplier making sure that there is not presence of organic matters, including clay, silts or loam. Sand was graded to pass No. 20 sieve and retained on No. 30 sieve.

2.1 Specific Gravity Determination

Test for specific gravity of YCHA was conducted using standard test method for density of hydraulic cement (ASTM C188). Specific gravity for different blends of cement replacements were tested in this procedure : 20% YCHA + 80% cement; 40% YCHA + 60% cement; 60% YCHA + 40% cement; 80% YCHA + 20% cement and 100% YCHA. Tests were performed by Test Lab Engineering and Geotech Services of Cagayan de Oro City.

2.2 Preparation of Specimens

Young coconut husk ash was used to replaced ordinary Portland cement at 20%, 40%, 60%, 80% and 100% by weight. Specimens without YCHA were also prepared to serve as control specimens of this study. Water-cement ratio of 0.485 and proportion of sand to cement is 1:2.75.

The fine aggregates, sand and cement were mechanically mixed in accordance with the procedure set in standard specifications for coal fly ash and raw or calcined natural pozzolan for use in concrete (ASTM C618). Specimens for compressive tests were molded using 2 in. cube steel moulds. The specimens were cast in 3 layers with each layer being tamped 35 strokes by a tamping rod. The molds and their contents were kept in the curing area at 27 ^{0}C for 24 hours and were removed and placed in a curing tank waiting for their tests at designated curing age at 7 days, 14 days and 28 days. The compressive strength is the average value of the three specimens at specified curing age.

Once respective compressive strengths of mortar are determined, the findings are compared to the minimum requirements set by standard specification for mortar for unit masonry (ASTM C270). These findings determine the suitability of using YCHA as cement replacement for concrete masonry application in the construction industry.

3. Results and Discussion

3.1 Chemical Test for Magnesium Oxide and Calcium Oxide

Tests for content of Magnesium oxide and Calcium oxide are presented in Table 1. Comparison with ordinary Portland cement is also shown to check difference of contents.

Results of the test revealed that there is presence of magnesium oxide (MgO) and Calcium oxide in YCHA. This means that YCHA can be considered as pozzolan characteristic for cementitious material.

Table 1. Magnesium Oxide and Calcium oxide content of YCHA

Content	**% Composition**	
	Young Coconut Husk Ash (YCHA)	**Ordinary Portland Cement (OPC)**
Magnesium Oxide (MgO)	1.52	1.00
Calcium oxide (CaO)	3.86	64.00

3.2 Time Setting Tests

The initial and final time setting of cement with or without YCHA are presented in Table 2. There is a need to compare these results to the Standard specifications of Portland cement as indicated in ASTM C150 in order to determine whether blended cement passed the specification requirements which specifies that setting time for cement must not be less than 45 minutes and should not exceed 375 minutes. Results showed that all cement blended with 60%, 80% and 100% YCHA did not passed the time setting requirement. This means that this study may focus on the YCHA with 20% and 40% replacement.

Table 2. Time Setting Tests of Cement (with or without YCHA)

% Replacement	**Cement weight (g)**	**Water (g)**	**Penetration (10+/-1mm)**	**Initial time**	**Final time**
0%	650	188	9	98	180
20%	650	215	9	78	95
40%	650	235	11	154	290
60%	650	245	9	360	400
80%	650	255	10	372	440
100%	650	265	10	380	460

3.3 Specific Gravity of cement (with and without YCHA)

Tests conducted for specific gravity on blended cements are presented in Table 3. It is observed that as the amount of YCHA increases, the specific gravity decreases. This means that design mixture of aggregate cement ratio need more water than what is normally considered when using YCHA as cement replacement.

Table 3. Specific gravity of blended cement

Cement Sample	Ambiance Temperature ^{0}C	Specific Gravity
0% - Ordinary Portland Cement (OPC)	27	3.15
20% YCHA + 80% OPC	28	2.93
40% YCHA + 60% OPC	27	2.78
60% YCHA + 40% OPC	26	2.66
80% YCHA + 20% OPC	27	2.51
100% YCHA	28	2.38

3.4 Comprehensive Strength

The compressive strength of mortar specimens without YCHA (100% OPC) is presented in Table 4.

Table 4. Compressive strength of the control specimens (without YCHA)

% of YCHA	Age in days	Specimen 1 (psi)	Specimen 2 (psi)	Specimen 3 (psi)	Average Compressive Strength (psi)
0%	7	1280	1650	1020	1317
0%	14	1530	1660	1130	1440
0%	28	1820	2040	2270	2043

These are the control specimens of this study. The compressive strength is the average value derived by the three specimens at specified curing age of mortar at 7 days, 14 days and 28 days.

Table 5. Compressive Strength of YCHA specimens at different mixture

% of YCHA	Age in days	Specimen 1 (psi)	Specimen 2 (psi)	Specimen 3 (psi)	Average Compressive Strength (psi)
20%	7	1480	1230	760	1157
20%	14	1650	1440	1390	1493
20%	28	1930	1400	1800	1710
40%	7	650	590	480	573
40%	14	380	600	820	600
40%	28	810	480	660	650
60%	7	310	410	310	343
60%	14	330	450	440	406
60%	28	370	520	550	480
80%	The specimens disintegrated during curing process				
100%	The specimens disintegrated during curing process				

The compressive strengths of the blended cement with YCHA is presented in Table 5. The 80% and 100% YCHA replacement failed to produce hardened mortar, which provided this study with information that replacement of more than 60% of YCHA is not feasible in this undertaking.

Table 6. The Average Compressive Strength of Mortar Specimens

YCHA Replacement	Average Compressive Strength (psi)		
	7 days	14 days	28 days
0%	1317	1440	2043
20%	1157	1493	1710
40%	573	600	650
60%	343	406	480
80%	0	0	0
100%	0	0	0

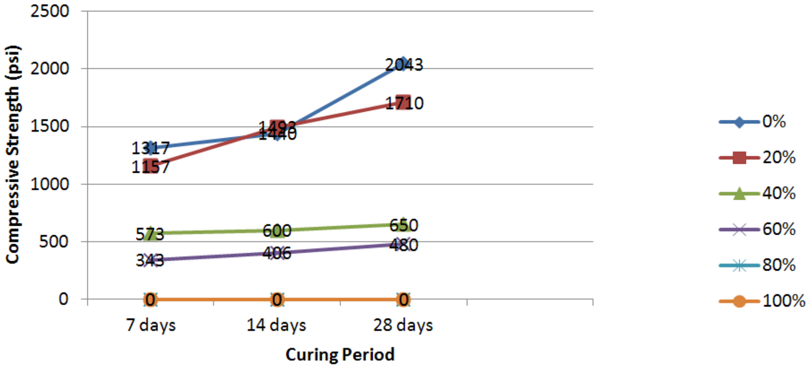

Figure 3. Compressive strength of mortar against curing period

The mortar being produced by partial replacement of YCHA derived the type of mortar characterized by the compressive strength attained during the tests at 28 day curing period. The ASTM C270 classified mortar type as to Type M, Type S, Type N and Type O as shown in Table 7.

Table 7. Minimum Requirement for Compressive strength of concrete in ASTM C270.

ASTM C270			
Type M	Type S	Type N	Type O
2500 psi	1800 psi	750 psi	350 psi

The 20% YCHA attained compressive strength of 1710 psi which classifies it as Type N mortar. This type of mortar is applicable for chimneys, block walls and exterior brick works.
The 40% and 60% YCHA replacement are classified as Type O mortar which is applicable for interior partition walls.

The results however, provided an encouraging implication for the use of young coconut husk ash as partial cement replacement to up to 60% by weight in which mortar produced are acceptable for certain type of construction application.

4. Conclusions and Recommendation

This study aims to determine the suitability of young coconut husk ash as partial replacement of cement in mortar preparation for construction application. The findings revealed that compressive strength obtained at 20%, 40% and 60% designed mixtures provide favorable applications for masonry applications.

Mortar at 20% cement replacement with young coconut husk ash as cement, derived compressive strength that met the specification requirement of ASTM C270 for Type N mortar while mortar at 40% and 60% YCHA replacement can be classified as Type O mortar.

It is recommended that partial cement with replacement YCHA may be used to up to 60% by weight depending on the masonry applications intended.

This study also recommends to conduct experimental investigation of using fly ash additives to mortar mixtures with 20%, 40% and 60% YCHA cement replacement in order to determine whether there is increase or (decrease) in compressive strength with partial addition of fly ash.

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