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An Experimental Investigation of Mahogany Carpel Ash as Cement Replacement in Concrete

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Abstract

This study investigates mahogany carpel ash as cement replacement at five different design mixtures: 20%, 40%, 60%, 80% and 100% mahogany carpel ash composition. Specimens without mahogany carpel ash were also prepared to serve as the control specimens for this study. The mortar specimens were tested for compressive strengths at curing age of 3 days, 7 days and 28 days. The characteristics of the ash were also determined to understand the physical and chemical contents of the ash. Results revealed that the use of 20% mahogany carpel ash cement replacement was able to meet the American Society for Testing and Materials (ASTM) C270 minimum strength requirement for Type M mortar. The 40% and 60% cement replacement met the minimum standards for Type N mortar and the 80% cement replacement met the minimum standards for Type O mortar. These findings provided information that may be useful to further conduct specific studies to enhance the utilization of mahogany carpel for concrete technology and the construction industry.

Keywords*:* mahogany carpel ash, cement replacement, pozzolan, compressive length

1. Introduction

The use of concrete as material for long-lasting infrastructure projects for the progress and development of countries all over world is a need that civilization cannot ignore. While cement existed for about 12 million years ago, concrete has been around for more than 5,000 years ago (Schaeffer, 1992). The use of concrete was noted during the construction of Egyptian pyramids (Davidovits and Morris, 1988). The Romans used concrete extensively from 300 BC to 476 AD, a span of more than seven hundred years (Gromicko and Shepard, 2016).

Research studies have been conducted to investigate the potential uses of waste agricultural materials for cement replacement. These included rice husk ash, peanut shell ash, corn cobs ash, saw dust among other organic materials that may be abundantly available in the locality.

According to Nimityongskul and Daladar (1995), expiremental investigation affirmed that coconut husk ash and corn cob ash cannot be used as cement replacement but peanut shell ash can be classified as class C pozollana according to ASTM standards. The suitability of coconut shell ash to partially replace cement was affirmed by several studies of Aho and Utsev (2008); Oyelade (2011); Utsev and Taku (2012).

Another study on partial cement replacement was conducted by Sumadi and Hussin (1995) on using palm oil fuel ash (POFA). Their findings disclosed that POFA satisfies the chemical and physical requirements for pozzolanic material specified by ASTM C618 (1991) and the ash is classified as Class F pozollans. The results also explained that replacing cement by POFA up to 20% is possible without affecting the compressive strength of concrete.

The study of Obilade (2012) investigated rice husk ash (RHA) as partial replacement for Portland cement in concrete at design mixtures of 0%, 5%, 10%, 15%, 20% and 25%. Mortar cubes specimens were tested for compressive strength at 7, 14 and 28 days of curing. Results acknowledged that compressive strength of hardened concrete decreases with increasing percentage of RHA replacement.

Raheem and Sulaiman (2012) and Obilade (2014) have studied about saw dust ash as partial replacement for cement in concrete. The study investigated the physical and chemical composition of saw dust ash (SDA) as well as workability and compressive strengths of concrete produced by replacing 5%, 10%, 15%, 20% and 25% by weight of ordinary Portland cement with SDA. The results showed that SDA is a good pozzolan with combined SiO_2, $AlS0_3$ and $FeSo_3$ of 73.07%, thus, it was concluded that 5% SDA substitution is adequate for maximum benefit of strength gain.

The mahogany trees, *Swietenia mahogani*, that grow in the Philippines belonged to the Toona species, commonly known as red cedar (ASEAN Tropical Plant Database, 2016). Philippine mahogany trees are of the genus Shorea and related genera, having brown or reddish wood used as lumber or furniture. Mahogany trees were introduced to the Philippines as early as 1907 and begun reforestation projects throughout the country (Anon, 2010). mahogany trees may reach over 60 m in height with trunk almost 3.5 m in diameter (Forest Generation, 2015). These trees produced fruits which are characterized by its hard shell called carpel as cover protecting the seeds inside (Figure 1).

Figure 1. Seed capsule of *Swietenia mahogani* showing the five sections (carpels) (Source: Armstrong, 2002)

Carpels are characterized by its very hard wooden material which people used for firewood because it produces charcoal when burned. All over the Philippines, mahogany trees have grown abundantly, wherein mature fruits are also scattered around these trees. Dried mahogany carpel are excellent fuel alternative for clay stove (Daray, 2011; Deponio *et al.*, 2015). Other studies on mahogany carpel application include its potential as potting media ingredient for healthy plants (Ramcharan and Gerber, 1982). No scientific works has been published relating mahogany carpel being used to cement replacement.

The aim of this study is to investigate the suitability of utilizing the mahogany carpel ash as partial cement replacement in mortar mix.

2. Methodology

The mahogany carpels used in this study were obtained from the mahogany trees in Cagayan de Oro City: in public schools, parks, and in the main campus of Mindanao University of Science and Technology. The carpels where carefully collected, removing other organic materials. These carpels were sundried for 2-3 days before burning process. Open burning was performed in a drum at about 600^0C. After cooling, the ashes were then collected and subjected for chemical testing, fineness and specific gravity determination.

The fine aggregates was obtained from local supplier making sure that it is free from clay, loam, dirt and other organic matters. Sand was graded to pass No. 20 sieve and be retained on No. 30 sieve. The cement used for this study is ordinary Type 1 Portland cement.

Preparation of Specimen

Mahogany carpel ash was used to replace ordinary Portland cement at 20%, 40%,60% , 80% and 100% by weight of cement. Mortar 1, with no mahogany carpel ash, served as the control specimens of this experiment. The water-cement ratio of 0.485 was used all throughout the mixtures. The fine aggregates, cement and water were mechanically mixed in accordance with the procedure set in ASTM C305 (1999).

Specimens for compressive strength test were molded using 150 mm cube steel moulds. The specimens were cast in three layers; each layer was being tamped with 35 strokes by a tamping rod. The top of each mold was smoothened and leveled and the outside surfaces were carefully cleaned. The molds and their contents were kept in the curing room at 27 ^{0}C for 24 hours.

Mortar molds were removed after 24 hours and placed in a curing cabinet, waiting for compressive testing of their designated curing periods at 3, 7 and 28 days. The compressive strength value is the average readings of the three specimens.

3. Results and Discussion

3.1 Chemical Composition of Mahogany Carpel Ash

The chemical composition of mahogany carpel ash is presented in Table 1. A comparison against its requirements from ordinary Portland cement is also presented to differentiate quantities. It can be noted that mahogany carpel ash obtained several constituents of ordinary Portland cement but in less quantities.

Table 1. Comparison of chemical composition of mahogany carpel ash and ordinary portland cement

Chemical Constituents	Mahogany Carpel Ash (Percentage by weight)	Ordinary Portland Cement (Percentage by weight)
Calcium Oxide (CaO)	20.04 %	60 – 65 %
Silicon Dioxide (SiO2)	2.30 %	17 – 25 %
Aluminum Oxide (Al2O3)	0.39 %	3 – 8 %
Magnesia (MgO)	3.76 %	1 – 3 %
Sodium Oxide (Na2O)	5.24 %	0.1 – 0.5 %
Iron Oxide (Fe2O3)	0.53 %	2 – 4 %
Sulfate (SO3)	0.69 %	1 – 2 %

The noticeable strong composition of mahogany carpel ash is on Magnesia (MgO) and Sodium Oxide (Na_2O). Magnesia is a chemical agent responsible for hardness of concrete. As a matter of fact, magnesia or magnesium oxide has been used as magnesium based cement in the 19th century before the introduction of Portland cement. On the other hand, sodium oxide controls the concrete residue. These findings indicate that mahogany carpel ash has pozzolanic materials in accordance to ASTM C618 (1991).

3.2 Compressive Strength

The compressive strength of mortar specimens was obtained using the compression testing machine. The compressive strength value is the average of three specimens at specified curing age of mortar at 3 days, 7 days and 28 days (Table 2).

Table 2. Compressive strength of mortar specimens

Mahogany Carpel Ash Replacement (%)	Compressive Strength (MPa)		
	3 days	7 days	28 days
0	16.1	24.5	32.4
20	8.7	15.6	19.1
40	7.8	9.3	11.6
60	7.0	8.1	8.5
80	0.9	2.8	3.4
100	0	0	0

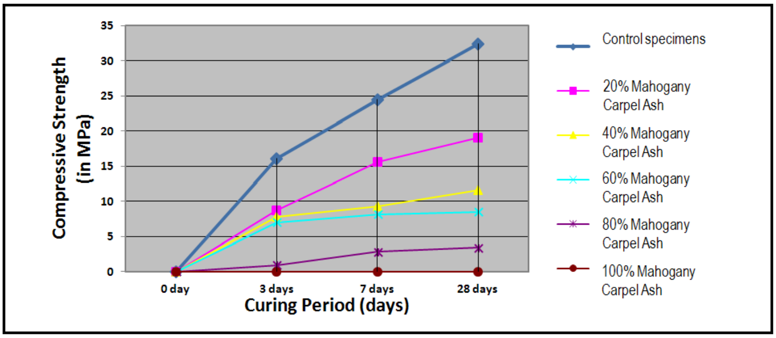

Figure 2. The compressive strength of mortar specimen against the curing period

The compressive strengths obtained were also presented in Figure 2 in order to show the graphical representation of the results. Compared to the control specimens (zero mahogany carpel ash), all the mortar obtained lesser compressive strengths even after the period of 28 days. Although compressive strength are lesser than the control specimens, these strength are acceptable according to ASTM C270 (2004) for minimum requirement for Type M, N and O mortars. The 20% mahogany carpel ash replacement comply the Type M mortar requirements, which is applicable for residential slab, retaining walls and driveways.

The 40% and 60% mahogany carpel ash replacements conformed the Type N mortar, which is applicable for chimneys, block walls and exterior brick works. Whereas, the 80% mahogany carpel ash replacement met the requirements for Type O mortar, which is applicable for interior partition walls.

The 100% mahogany carpel ash replacement was not considered for testing since it did not produce a hardened concrete mortar. These specimens disintegrated after removal of forms, hence, not feasible for this study. The following results present positive implications for the use of mahogany carpel ash as cement replacement up to 80% by weight.

4. Conclusions and Recommendations

This study aims to determine the feasibility of mahogany carpel ash as partial substitute for cement material in mortar preparation. The results of this study showed that compressive strength obtained at different design mixes were favorable for its use except for 100 percent replacement.

It is therefore possible to use mahogany carpel ash as cement replacement to derive a mortar mix at different percentage ratios. The highest compressive strength which met the ASTM C270 Type M standards can be attained to cement replacement of up to 20%. More than 20% reduces the compressive strength of the mortar with Type N (for 40% and 60% replacement) and Type O (80% replacement).

This study recommends conducting an experimental investigation of using mahogany carpel ash to concrete mix, whereby coarse aggregates will also be considered. Having determined that the design mixture of 20 percent cement replacement was able to meet the ASTM 270 for Type M mortar; it is also recommended that cement replacement for 5%, 10%, 15% and 20% should be focused for future studies in concrete design mixture.

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