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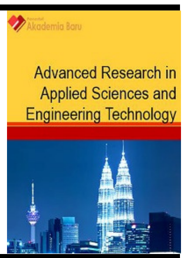

Sustainable green interlocking pavement block

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ABSTRACT

In accordance upon conservation efforts, this research emphasizes on prevention of environmental pollution and considers the elements of sustainable of infrastructure construction materials, which is interlocking pavement block. The development of this innovative product apply the concept of 3Rs and waste to wealth by using the agricultural waste product, coconut shell, where widely available with very minimum cost worldwide especially in tropical country such as India, Indonesia, Philippines, Thailand and Malaysia. The main objective of this research is to produce an environmental friendly product with a good quality, low cost and lightweight known as Green Interlocking Pavement (GIP Block). The chemical composition of coconut shell ash and ordinary Portland cement being identified and compared to know whether it is able to react as a good binder in the mixture or not. The quality of GIP Block considered is compressive strength, water absorption and bulk density. All the blocks were curing in seven and 28 days before implementing the entire test. The existing interlocking pavement used as bench mark and GIP Block 0% of proportion of coconut shell ash used as control variables. The specimen of the interlocking pavement prepared in this research is 10%, 20% and 30% proportion of coconut shell ash to partially replace the quantity of cement. The ratio of the interlocking pavement apply in this research is 1:2 which stand for one part cement and two part of sand. The findings withdrawn from this research are: first, the chemical characteristic of the coconut shell ash and cement. Second, the value of bulk density slightly reduces as the percentage of coconut shell ash increases. Third, the additional of coconut shell ash to partially replace the quantity of cement in the product reduce the compressive strength and increase the percentage of water absorption.

1. Introduction

Interlocking pavement block was produced in a various shapes and colour with a wide variety in dimension. The most commonly used are the square, hexagon and multiple hexagon shapes. Interlocking pavement blocks have multiple advantages which are: fast in assembling, replacement and transportation; excellent drainage capacity, easy handling and fast production. In many countries

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such as Indonesia, Malaysia, Brunei and others, interlocking pavement blocks are widely used for all sorts of purpose starting from parking spaces, parks, to heavy duty roads. The paving blocks in such countries are also used to beautify the appearance of a road [8]. The production of interlocking pavement needs cement. Cement release green-house gases which leading to global warming [5]. Cement also causes many environmental problems, such as air pollution and the depletion of natural flora and fauna [2]. In the other hand, disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob and coconut shell have constituted an environment challenge [9]. Yerramala and Ramachandrudu [10], mention that, according to previous report coconut is grown in more than 86 countries worldwide, with a total production of 54 billion nuts per annum with India occupies the premier position in the world with an annual production of 13 billion nuts. All this production of coconut may contribute to pollutions. Coconut shell aggregate is a possible construction material and concurrently reduces the environmental problem of solid waste as well [6]. Recently, efforts has been made on the application of agricultural waste product, which is coconut shell, as lightweight aggregate to produce structural lightweight concrete [4]. So, the Green Interlocking Pavement (GIP) Block able to solve pollution cause by cement and the billion nuts of waste of coconut shell.

Moreover, according to Dhanalakshmi *et al*. [1], the use of agricultural waste product not only be economical, but it may increase the income of our country and environmental pollution can be controlled as well. According to Lopa Shinde *et al*. [6], recycling of such wastes and using them in construction materials may appears to be feasible solution not only to the environmental pollution problem but also an economical option in construction. There are necessary to look for save cost materials to replace partial quantity of cement and the material suggested is agricultural waste products such as rice husk, corn cob and coconut shell which is readily available with of course low cost. Research indicates that most materials that are rich in amorphous silica can be used in partial replacement of cement [9]. Through previous study, coconut shell are detected has similar properties with cement which can be used in order to reduce the quantity or cement in a concrete [9,10]. In tropical country like Malaysia, there are a lot of coconut shells that can be converted into useful materials to minimize their negative effect on the environment. In this study, the main objective is to produce a save cost and environmental friendly product known as Green Interlocking Pavement Block (GIP Block) which using recycled coconut shell to partially replace the quantity of cement in the pavement block.

2. Material and Methods

2.1 Preparation of Samples

2.1.1 Prepare aggregate

Fine aggregate, sand, was used in order to cast interlocking pavement blocks. The specific gravity of sand is 2.68. Those fractions from 4.75 mm to 150 microns are termed as fine aggregate [1]. In this research, the size of sand sieved is 2 mm.

2.1.2 Prepare coconut shell ash (CSA)

CSA stand for Coconut Shell Ash. Coconut shell has been burned to obtain the ash. Collect the ash and put it in oven to remove moisture content. Sieve the ash passing particle size of diameter below 0.075 m. It was then subjected to uncontrolled combustion using open air burning for three hours and allowed to cool for about 12 hours. The burnt ash was collected and sieved through a BS sieve

75 microns [9]. But, in this research, burnt the coconut shell in furnace has been chosen due to the environmental friendly campaign by following:
The coconuts were procured from a nearby local temple. The coconuts were broken manually to drain out the water. The 40 coconut half shells were sun-dried for three days. Sun drying was necessary to ease removal of the meat from the inner shells of the coconut pieces. After scraping the meat from the inner shells, the inner portions of the shells were cleaned using knives. The fibers on the outer shells were also scraped and cleaned. Emery paper was used to clean the outer shells. The cleaned coconut shells obtained from were cut into pieces of dimensions of 1 sq.cm using hammer and were put in stainless steels containers. The containers were then kept into muffle furnace for carbonization (carbonization is the production of charred carbon from a source material. The process is generally accomplished by heating the source material usually in the absence or limited amount of air to a temperature sufficiently high to dry and volatilize substances in the carbonaceous material). The carbonization temperature selected as 600 and 800 degrees. After a soak time of 4 hours, the sample gets carbonized. As the furnace cools down, containers were taken out [7].

2.2 Mix and Cast

Coconut shell ash has been mixed with cement following the predetermined percentage and fine aggregate which is sand sieved 2 mm. The coconut shell ash was added in various proportions as part of cement replacement. The ratio applied for Green Interlocking Pavement is 1:2 which stand for one part of cement and two parts of sand. Meanwhile, the water-cement ratio is constant 0.6 for all samples. Clean the mould properly and apply oil on inner surface of the mould. Pour the mixture in a mould. Put it on vibrator to increase the strength by compacting the mixture and remove void in the mixture. Then, let the mixture rest in the mould for 24 hours before taken out to proceed with next testing.

The sieved ash were mixed with cement in order to replace the quantity of cement with 0%, 10%, 20%, and 30% of coconut shell ash. For example, the first samples contain 0% of coconut shell ash mixed with 100% of cement. The second samples contain 10% of coconut shell ash partial replace the cement and the cement used only 90% from the volume ratio. The third samples contain 20% coconut shell ash mixed with 80% of cement. The forth samples contain 30% coconut shell ash mixed with 70% of cement.

2.3 Curing

Curing plays a significant role on development of strength and durability of concrete. Curing of concrete test in laboratory is different from concrete during construction. So, American Society for Testing and Materials (ASTM) has developed two standards for making and curing concrete specimens. ASTM C192 provides procedures for evaluation of various laboratory samples. While, ASTM C31 is intend for on-site construction samples. The purposes of curing is to maintain mixing water in concrete for the early period of hardening process, to reduce the loss of mixing water from the concrete and to gain strength by using additional moisture. The Green Interlocking Pavement was cured for 7 days and 28 days after it is taken out from the mould and before proceeds with Compression Test.

2.4 Compression Test

Compression Test will be applied on 18 blocks of Green Interlocking Pavement, six blocks for control variable and three blocks of Existing Interlocking Pavement. Compression Test is very significant to determine the compressive strength for products which receive vertical loading. The compressive strength of the interlocking pavement samples was determined after the samples have been cast and cured for 7 and 28 days. The weight of the interlocking pavement samples were taken before conducting the compressive strength test. Samples were crushed with the cast faces touch with the testing machine at 7 and 28 days using the Compression Testing Machine available in the concrete laboratory in School of Environmental Engineering of UniMAP.

Compressive Strength = Maximum Load (N)/Load Area (mm^2) (1)

2.5 Water Absorption Test

According to Ganesan *et al*. [3], the water absorption test is conducted to determine the pore volume and porosity in harden concrete. The total water absorption of the sample is defined as the increment in the weight of a sample due to moisture in air. Before the test was conducted, specimens has been dried at least for 48 hours at 110°C and samples were weighed several times to ensure the water content inside the specimens were fully dried observe the content weight of the samples to assure it reach constant weight as mentioned in Clause 40 in Malaysian Standard (MS76:1972). After the samples fully dried, weight of all the samples has been recorded before water absorption test was conducted. Then, the specimens were completely immersed, without preliminary partial immersion into a water tank at room temperature for 24± 1 hour. The specimens were removed immediately from the water tank and the surface was wiped with a damp cloth. Within two minutes after its removal from water, the samples were weighted and the data was recorded. According to Clause 40, Water Absorption Test in Malaysian Standard (MS76:1972), the result shall be described in terms of percentage increase by weight on the dry samples and can be calculated to the nearest percentage. In this research, there are 18 samples involved in this test. Each samples were dried into an oven for 48 hours at temperature of 110°C.

Water Absorption = $(Ms - Md)/Md$ x 100% (2)

where; ws is mass of saturated block and Wd is mass of dry block after dried in a ventilated oven at a temperature of 105 °C. to 115 °C.

2.6 Bulk Density Test

The bulk density is calculated as mass per unit volume;

Bulk Density = Mass (M) / Volume (V) (3)

where; M is the weight of the specimen after dried in a ventilated oven at a temperature of 105 to 115 , while V is the volume (length x width x height) of the block.

3. Results and Discussion

3.1 Chemical Characteristic Coconut Shell Ash and Ordinary Portland Cement

Table 3.1a and Table 3.1b shows the chemical characteristic of coconut shell ash (CSA) and ordinary Portland cement (OPC) by using X-Ray Fluorescence (XRF) Test.

Table 3.1a
XRF Test result of CSA

Element	Percentage (%)
Silicon, Si	3.0
Sulfur, S	1.97
Potassium, K	46.7
Calcium, Ca	28.4
Iron, Fe	2.95

Table 3.1b
XRF Test result of OPC

Element	Percentage (%)
Silicon, Si	5.64
Sulfur, S	2.27
Potassium, K	1.11
Calcium, Ca	83.78
Iron, Fe	3.86

3.2 Compressive Strength

The result shows from compression test is that if the percentages of coconut shell ash increases, the compressive strength will decrease. Green Interlocking Pavement and Existing Interlocking Pavement referred as GIP and EIP respectively. The average result of EIP is 47.826 MPa. The average result for GIP will be shown in Table 3.2a and Table 3.2b.

Table 3.2a
Compression test result of GIP curing for 7 days

Types of GIP	Compressive Strength (MPa)
GIP (0%)	45.914
GIP (10%)	28.817
GIP (20%)	23.138
GIP (30%)	18.637

Table 3.2b
Compression test result of GIP curing for 28 days

Types of GIP	Compressive Strength (MPa)
GIP (0%)	46.809
GIP (10%)	29.119
GIP (20%)	25.868
GIP (30%)	19.127

Although the compressive strength of Green Interlocking Pavement (GIP-Block) which contain 30% of coconut shell ash is different much from the existing block, yet it is still can be used for landscape purpose. The GIP-Block contain 10% and 20% of coconut shell ash can be used for pedestrian. The function can be used in different way and yet it is still have advantages which is a 'green' landscape, pedestrian or car park can be create and indirectly show awareness toward environmental friendly. In other hand, it is economical compared to existing interlocking pavement block in market.

3.3 Water Absorption

Interlocking pavement block are installed outdoor. It is used for infrastructure in construction project such as pedestrian, landscape, car park and others. As it is expose to environment outdoor, it is will expose to rain and sun for sure. The average result for Existing Interlocking Pavement (EIP) is 4.27%. Table 3.3 shows the average result of water absorption test for Green Interlocking Pavement (GIP).

Table 3.3
Water absorption test result of GIP curing for 28 days

Types of GIP	Water Absorption
GIP (0%)	9.08
GIP (10%)	10.60
GIP (20%)	12.97
GIP (30%)	14.13

Although the percentage of water absorption increase due to percentage of coconut shell ash increase, this situation is not affect strength much. It is only used on the ground surface and not affect others structure.

4.0 Conclusion

From the result of XRF obtained prove that, coconut shell ash (CSA) and ordinary Portland cement (OPC) can be mixed and indirectly shows that the cost of construction product can be reduce by reducing the quantity of cement replaced by agricultural waste product which available in extreme cheap cost. The CSA makes the product lightweight, environmental friendly and economic. The result from water absorption test shows that the GIP Block absorb water more compared with EIP Block. In other hand, the result of compression test shows that the GIP Block can be used multifunction as discuss above and the result of bulk density test prove that the product mixed with CSA is lightweight. Further areas of research are always recommended regarding recycle the agricultural waste materials into useful product.

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