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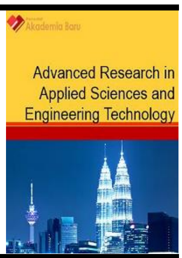

Sustainable Green Concrete by using Biomass Aggregate

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ABSTRACT

The use of concrete for construction had become very common in developing countries. But concrete is not friendly environment because of it consumes huge quantities of natural materials and production of the cement, which is a major contributor to greenhouse gas emissions and global warming. The aim of this study is to investigate the Sustainable Green Concrete (SGC) which containing biomass aggregate; fly ash and Superplasticizer. Biomass aggregate and fly ash are waste industry products which are environmentally friendly. The study was carried out to identify the chemical properties of biomass aggregate, and to determine the chemical properties and optimum mix design of the Sustainable Green Concrete (SGC). A total of 90 cube samples were casted and compressive strength were tested at the age of 7, 14 and 28 days. The overall results showed that the workability and compressive strength were decreased with the increase of the replacement of natural aggregate with biomass aggregate. Besides that, the workability and compressive strength was increased with the incorporation with the replacement cement by fly ash. The SGC gained highest compressive strength for the concrete mixes of 39.3 N/mm^2 with the optimum percentage used of SGC in producing concrete not exceeding 30% biomass aggregate and 6% of fly ash as a partial replacement with natural aggregate and cement respectively. The results obtained and observation made in this study suggested that biomass aggregate and fly ash are successfully used as partial replacement in producing SGC and can perform better strength development.

Keywords:
Sustainable Green Concrete (SGC);
Biomass Aggregate (BA); Fly Ash (FA);
compressive strength; workability

1. Introduction

Based on Valeria *et al.* [1] Pravin *et al.,*[2], traditionally the Concrete industry has been considered a major producer of Greenhouse gas (GHG) emissions, mainly due to the high environmental footprint of cement. Based on the Desai *et al.,* [3], the use of supplementary cementitious material (SCM) such as fly ash, blast furnace slag, silica fume and biomass aggregate from waste material has been widely used for the application and development sustainable concrete or green concrete. The common SCMs studied included, but may not be limited to fly ash, furnace slag, and silica fume [4-6]. Other researchers have also investigated some alternative aggregates (AA), such as building rubbles, oyster shell, recycled concrete aggregate (RCA), and waste-expended polystyrene reground material [7-10]. Based on the research conducted by Mark *et al.,* [11] structural and durability test

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showed that High Performance Cement (HPC) containing fly ash and 50% recycled aggregate performed equally or better than 100% ordinary portland cement concrete with the same cementitious content [11]. But based on Limbachiya *et al.,* [12] concluded that 30% of Recycled Concrete Aggregate (RCA) replacement decreased concrete strengths [12]. However, sustainable green concrete studies were hardly available in Malaysia. Based on Lepech *et al.,* [13] to achieve high strength in the Sustainable Green Concrete, the use of supplementary cementitious materials (SCMs), recycled aggregates and other industrial wastes are encouraged.

2. Methodology

The raw materials for this study are Ordinary Portland Cement (OPC) with class strength 42.5, natural fine aggregates and granite, biomass aggregate, fly ash, superplasticizer (Supracoat SP800) and water. The biomass aggregate used is burning plywood waste which was obtained from LingShanhao Plywood Sdn Bhd, WTK Holdings located at Demak Laut Free Industrial Zone, Kuching, Sarawak as shown in Figure 1. The fly ash used is coal waste from Sejingkat Power Corporation Sdn. Bhd. Kuching which was obtained from Gobel Industry Sdn. Bhd. located at Jalan Bako, Kuching Sarawak. The maximum size of natural fine aggregates comply with BS EN 12620 is 4.75mm [14] which passed through the sieve analysis conducted.

Fig. 1. Biomass aggregate from waste burning plywood

The determination of chemical composition of biomass aggregate will be done by using Standardless Method of X-Ray Fluorescence (XRF) test. Bulk density test of fine aggregates and granite will be conducted. The aggregate impact value (AIV) test is carried out to access the suitability of aggregate as regards the toughness for use in construction work. The aggregate impact value was expressed by Eq. 1 and compared with the strength characteristic of Aggregate Impact Value (AIV) as in BS812: 112: 1990.

$$\text{AIV} = \frac{\text{Weight of the portion of crushed material passing 2.36 mm sieve, } W_2 \text{ (g)} \times 100\%}{\text{Total weight of dry sample, } W_1 \text{ (g)}} \tag{1}$$

The aggregate crushing value (ACV) is an indirect measurement to determine the crushing strength of the aggregates [15]. The aggregate crushing value was expressed by Eq. 2 as below:

$$\text{ACV} = \frac{\text{Weight of the portion of crushed material passing 2.36 mm sieve, } W_2 \text{ (g)} \times 100\%}{\text{Total weight of dry sample, W1 (g)}} \tag{2}$$

The workability of fresh SGC was measured to the nearest 5 mm using the ruler and the results is valid if it yields a true slump, this being a slump in which the concrete remains substantially intact and symmetrical according to BS 1881: Part 102: 2013 [16]. The SGC dry density will be recorded after

28 days curing before conducting the compressive strength to determine the weight changing compared with control specimens.

The compressive strength was carried out at the age of 7, 14 and 28 days of water curing and subjected to the maximum compression axial loads applied. In term to obtain the compressive strength, it can be calculated by using Eq. 3 according to BS 1881: Part 116: 1983 [17].

$$\text{Compressive Strength, } \sigma = \frac{\text{Max. Axial Load Applied (N)}}{\text{Cube Cross-Sectional Area (mm}^2\text{)}} \tag{3}$$

There were SIX (6) series of concrete mix which consist of Biomass Aggregate (BA) and Fly Ash (FA). There were SIX (6) categories of concrete mixes and a total of Ninety 150 x 150 x 150 mm cubes specimens were prepared to determine the concrete compressive strength. The mix proportions for the present study are tabulated in Table 1.

Table 1
Concrete Mix Design for Sustainable Green Concrete

Batches/ Series	Water/ cement Ratio	Biomass Aggregate (%)	Fly Ash (FA) (%)	Cement (%)	Natural Aggregate (%)
A	0.35	0	0	22	78
B1	0.35	15	0	22	63
B2	0.35	30	0	22	48
C1	0.35	30	4	18	48
C2	0.35	30	6	16	48
C3	0.35	30	8	14	48

Source: Concrete Mix Design from SCIB Concrete Manufacturing Sdn Bhd, Junda Realty Sdn Bhd, Kuching & Cemex
1) Dosage of Suprachem SP800 per 100kg of cement (KG) = 0.60
2) Type of coarse aggregate: Granite

3. Results

3.1 Properties of Raw Materials

The mass and bulks densities of cement, fly ash, natural fine aggregate, granite and biomass aggregate are summarized in Table 2. The result showed the compacted bulk density with high increasing with biomass aggregate which are 26.15% after the compaction by using steel rod in the cylinder steel mould. According to the Suraya, H. A. *et al.,* the result indicated biomass aggregate contain porous particles which are breakable but there was ability to enhance the concrete water permeability if compare to granite [18].

Table 2
Mass Properties of Raw Materials

Materials	Loose Bulk Density (kg/m^3)	Compacted Bulk Density (kg/m^3)	Loose Versus Compacted (%)
Cement	929.55	-	-
Fly Ash	909.34	-	-
Natural Fine Sand	1212.45	1333.70	9.09%
Granite	1010.38	1293.28	21.88%
Biomass Aggregate	969.96	1313.49	26.15%

3.2 Chemical Composition for Biomass Aggregate

The results in Table 3 showed that biomass aggregate contain 65.30% of Silicon Dioxide (SiO2) which has similar chemical properties of cement and silica fume. According to [19], silica fume which has a higher surface area and higher Silicon Dioxide (SiO2) content will help to increase the strength development of the concrete itself through reactivity to the rate of hydration fraction of the cement in the first instance.

Table 3
Chemical Compound of Biomass Aggregate

Chemical Name	Formula	Concentration (%)
Orig	g	8
Added	g	2
Carbon dioxide	CO_2	0.10
Silicon dioxide	SiO_2	65.30
Calcium oxide	CaO	0.63
Chloride	CI	1.41
Aluminium oxide	Al_2O_3	15.50
Sodium oxide	Na_2O	1.44
Iron oxide	Fe_2O_3	5.12
Magnesium oxide	MgO	0.66
Potassium oxide	K_2O	5.68
Sulfur Trioxide	SO_3	1.17
Titanium oxide	TiO_2	1.37
Phosphoros	P	0 < LLD

Note:*Using Standard less method, measured from Na to U (refer to periodic table)
** 1% = 10, 000 ppm

3.3 Aggregate Crushing Value (ACV) & Aggregate Impact Value (AIV) for Biomass Aggregate

The experimental result in Table 4 obtained showed that the ACV value for biomass aggregate was 29.0% while AIV value was 26.5%. According to BS 882: 1992, biomass aggregate can be classified as good material or enough stronger to use for the concrete mix because their crushing value of 29.0% is lower to the limit value which there have enough ability to resist crushing [20]. Besides that, the AIV test showed that the aggregate not significant affected by the impact load which is 26.5% only. According to BS 882, biomass aggregate can be classified normal strength used for concrete.

Table 4
Aggregate Crushing Value (ACV) & Aggregate Impact Value (AIV) for the Biomass Aggregate

Physical Properties Biomass Aggregate		BS 882:1992 Classification (Not exceeding %)
Aggregate Crushing Value (ACV) %	Aggregate Impact Value (AIV) %	
29.0	26.5	< 25 (Heavy duty concrete floor) < 30 (Pavement wearing surfaces) 50 (Others)

3.4 Workability for Sustainable Green Concrete

Based on Figure 2, the slump value decreases occurred due to the increase of biomass aggregate as partial replacement for granite because this type of aggregate is produced from combustion process which consumes more water for the reaction as Pozzolanic materials. The results also showed that fly ash added will increase the concrete slump because the fly ash will react as a water reducer which is important to improve the workability, rheological properties of fresh concrete and ultimate strength as well as durability of hardened concrete [21].

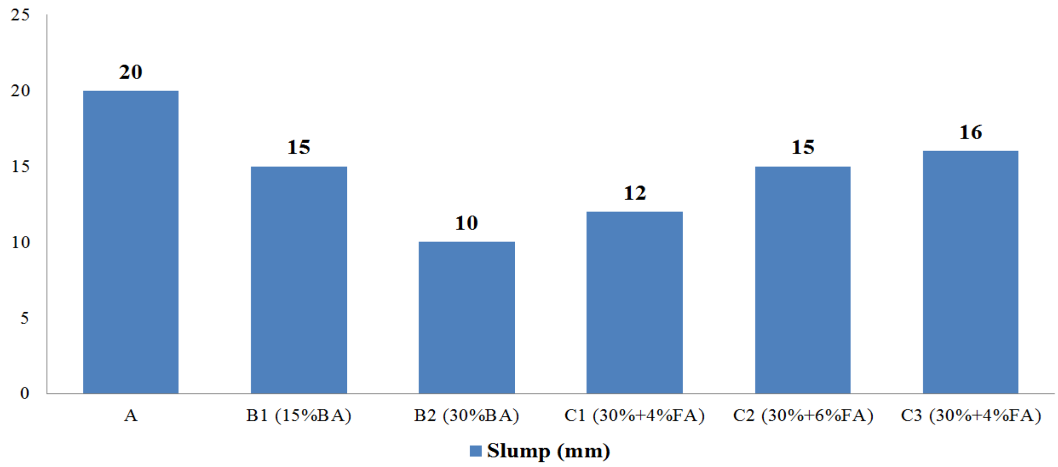

Fig. 2. Sustainable Green Concrete Slump

3.5 Compressive Strength for Sustainable Green Concrete

The data in Table 5 presented that the compressive strength of concretes mixes with biomass aggregate (Series B1 & B2) was lower than that of control/ original mix (Series A). In this study, it was found that the use of 30% biomass aggregate in conjunction with 6% fly ash achieved higher compressive strength of 39.3 N/mm^2.

Table 5
Compressive Strength for Sustainable Green Concrete

Batches/	Average Compressive Strength, σ = P/A (N/mm^2)			Concrete Mix
Series	7 days	14 days	28 days	
A	25.2	32	35.1	Original
B1	23.7	29	34.4	15% BA
B2	21.6	23	29.1	30% BA
C1	21.5	27	32.0	30% BA + 4% FA
C2	25.7	33	39.3	30% BA + 6% FA
C3	23.2	29	33.6	30% BA + 8% FA

3.6 Statistic Analysis for the Compressive Strength

Based on the results obtained in Table 6, the standard deviation of the compressive strength for the all SIX (6) series concrete mixes will be considerably low standard deviation means with standard deviation range between 1.60 to 4.74 which the data are tightly clustered or scattered around the mean; the concrete mixes with biomass aggregate and fly ash are smaller variability than the control at 28 days for the compressive strength which has high standard deviation means that they are widely scattered for control/ original concrete mixes. The COV results obtained also showed that the confident of the data collected and the quality of experimental work done was in good condition.

Table 6
Mean samples, standard deviation and coefficient of variance for the compressive strength

Mean			Standard Deviation			Coefficient of Variance (COV) %			Note
7 Days	14 Days	28 Days	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days	
25.24	31.56	35.11	0.96	0.87	4.74	3.82	2.76	13.49	Original
23.73	29.07	34.40	1.86	1.12	3.69	7.85	3.86	10.72	15% BA
21.60	22.67	29.07	2.05	2.01	1.60	9.50	8.88	5.51	30% BA
21.51	26.67	32.00	2.10	2.00	2.14	9.76	7.50	6.68	30% BA + 4% FA
25.73	33.07	39.29	3.87	3.60	3.41	15.05	10.88	8.67	30% BA + 6% FA
23.20	29.16	33.60	1.74	1.74	1.60	7.50	5.97	4.75	30% BA + 8% FA

4. Conclusions

Based on the findings of this study, all the experimental data shows that the replacement of the biomass aggregate will decrease concrete strength but the replacement of the fly ash will improve the concrete properties. This is because the chemical compositions of biomass aggregate consist 65.3% Silicon Dioxide (SiO2) will create the pozzolanic reaction with the calcium hydroxide (Ca(OH)2) or lime in Portland cement. But in SGC development, this pozzolanic reaction does not help to increase the strength development of the concrete itself because of the water adsorption by biomass aggregate will affect the workability and compaction in the concrete mixes. However, the replacement of fly ash to concrete is able to provide as high improvement levels which shown in the replacement of granite with 30% biomass aggregate and 6% fly ash gives an excellent result in strength and quality aspects. Finally, the compressive strength results also indicated that the optimum percentage used for SGC as partial replacement in producing concrete was 30% biomass aggregate plus 6% fly ash. It can be seen that the compressive strength for the concrete mixes Series C2 performed the highest compressive strength at the age of 28 days which were 39.3 N/mm^2 while others of percentage replacement showed the decrease for compressive strength. These results are of great importance because this kind of innovative concrete requires large amounts of fine particles. From the above study, it is concluded that the biomass aggregate and fly ash can be used as a replacement material for coarse aggregate and cement in the concrete mixes. The following recommendations may be made based on the conclusions from this study such as further tests with longer curing ages such as 60 and 90 days should be investigated.

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