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Compressive strength performance of OPS lightweight aggregate concrete containing coal bottom ash as partial fine aggregate replacement

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Abstract. Concerns regarding the negative impact towards environment due to the increasing use of natural sand in construction industry and dumping of industrial solid wastes namely coal bottom ash (CBA) and oil palm shell (OPS) has resulted in the development of environmental friendly lightweight concrete. The present study investigates the effect of coal bottom ash as partial fine aggregate replacement towards workability and compressive strength of oil palm shell lightweight aggregate concrete (OPS LWAC). The fresh and mechanical properties of this concrete containing various percentage of coal bottom ash as partial fine aggregate replacement were investigated. The result was compared to OPS LWAC with 100 % sand as a control specimen. The concrete workability investigated by conducting slump test. All specimens were cast in form of cubes and water cured until the testing age. The compressive strength test was carried out at 7 and 28 days. The finding shows that integration of coal bottom ash at suitable proportion enhances the strength of oil palm shell lightweight aggregate concrete.

1. Introduction

Malaysia is one of the largest palm oil producing country in the world. At the same time, the palm oil processing mills are generating many types of wastes. As the palm oil industry continues to grow, more wastes are generated. These wastes when disposed cause environmental pollution and destroy the habitats of flora and fauna. The importance of preserving the cleanliness of environment for present and future generation, has motivated many researches to be carried out to turn these wastes such as oil palm shell (OPS), palm oil clinker, empty fruit bunches, palm oil fibres and palm oil fuel ash into profit generating element. Oil palm shell is one of the wastes which continuously generated in increasing amount by palm oil mills. Approximately 6.89 million tonnes of OPS were generated annually by Malaysian palm oil mills [1]. This waste which obtained after the oil extraction process usually dumped as waste in the factory's compound. The continuous dumping of these wastes causes larger land consumption in the factory area which can be utilized for more beneficial purposes. From the view of environmental sustainability, the dumping of waste is causing environmental pollution [2, 3]. As one of the solutions to this problem, palm oil mills need to spend extra expenditure to manage these wastes. However, integrating this waste material in production of useful materials would reduce quantity of waste ending at landfill. Besides that, coal bottom ash which is a solid waste generated from local coal industry also causes negative impact to the environment. The dumping of this waste also causes environmental problems such as contamination of ground and surface water. According to



Rafieizonooz et al. [4] the projected forecast for electricity usage in peninsular Malaysia will be produced from coal and gas (58% and 25%) by the year 2024. Thus, it is expected that production of coal bottom ash would increase and poses more environmental problem unless it is converted into beneficial product.

At the same time, the development of construction industry has resulted in increasing use of natural sand for construction. Based on the report by Department of Minerals and Geosciences of Malaysia, the sand mining activities in Malaysia have been trending in increasing mood which made a difference from 37.3 million tonne in 2011 to 46.7 million tonne in 2016. Increasing sand mining activity exposes the environment quality degradation issues such as destruction of natural habitats, soil erosion and reduced river water quality due to excessive mining activity. These environmental problems occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials [5]. Discovery of other alternative material to reduce the use of natural sand would be able to preserve nature resources and contribute to sustainable construction. The environmental problems caused by dumping of solid wastes and increasing sand mining activity have led to the effort of integrating waste material as partial sand replacement in oil palm shell lightweight aggregate concrete. Past researchers [2, 6, 7, 8, 9] has investigated the properties and potential of oil palm shell lightweight aggregate concrete. However, no experimental findings are available on the use of coal bottom ash as partial sand replacement in this lightweight concrete. Thus, the present research aims to investigate the effect of integrating coal bottom ash as partial sand replacement in OPS lightweight concrete.

2. Methodology

2.1. Materials

The materials used in this experiment are ordinary Portland cement, local river sand, water, water reducing admixture, oil palm shell (OPS) and coal bottom ash (CBA). Tap water at the laboratory was used for concrete mixing and curing work. Coal bottom ash (CBA) shown in Figure 2 was supplied by one of the coal power plant located in West Coast Malaysia. Oil palm shell (OPS) in Figure 1 was supplied by nearby palm oil mill located in the state of Pahang, East Coast Malaysia. The properties of OPS used in this research are tabulated in Table 1.



Figure 1. Oil Palm Shell (OPS).



Figure 2. Coal Bottom Ash (CBA).

Table 1. Properties of oil palm shell aggregates.

Properties	Oil palm shell
Maximum size (mm)	10
Specific gravity	1.19
Density (kg/m ³)	1481
Water absorption for 24 h (%)	16.57
Aggregate abrasion value, (%)	6.9
Fineness modulus	6.33
Flakiness index (%)	65.17
Elongation index (%)	12.36
Aggregate impact value (%)	6.47
Aggregate crushing value (%)	5.71

2.2 Mix Proportion and Testing Procedure

A total of 5 mixes were used in experimental work. Mix containing 100% OPC was used as control specimen. The rest of the mixes were prepared by varying the percentage of CBA at 5%, 10%, 15% and 20% by weight of sand. Prior to mixing process, all the materials were weighed accurately. Then, all the mixing ingredients were mixed uniformly before cast in form of cubes of 100mm. The cubes were demoulded the next day and subjected to water curing. In order to determine the concrete workability, freshly prepared mixed were immediately subjected to slump test. The slump test was conducted following the procedure in ASTM C143 [10]. The effect of CBA content on the concrete strength is determined through compressive strength test adhering to the procedure in BS EN 12390 [11]. The test was conducted at 7 and 28 days.

3. Results and discussion

3.1 Workability

The result of slump test conducted on mixes containing various percentage of coal bottom ash (CBA) is illustrated in Table 2. It can be observed that the inclusion of CBA affects the workability of concrete. As the percentage of CBA is added in the mix becomes higher, the concrete mix become stiffer resulting in lower slump value. One of the contributing factors is higher water absorption by the porous particles of coal bottom ash. The porous particles of coal bottom ash absorbed water internally causing reduction in free water for lubrication of particles resulting in lower slump. The influence of aggregate characteristic towards concrete workability has been highlighted by Neville [12]. Similar trend has been observed by past researchers [13, 14] who investigated the effect CBA as partial sand replacement on concrete workability.

Table 2. Slump test result

Mix with CBA %	Slump Value	Slump Classification
0%	100	High
5%	85	Medium
10%	75	Medium
15%	60	Medium
20%	5	Very Low

3.2 Compressive Strength

Figure 3 presents the compressive strength test result of specimens containing various content of CBA as partial fine aggregate replacement. Looking at the effect of CBA as partial sand substitute, the strength gain of the concrete with CBA was superior to that of the control mix as the percentage of CBA replacement was increased to up to 20%. However, the highest compressive strength was obtained when the sand is replacement with 15% of CBA by weight. The strength gain of that particular mix is 14% higher than the control specimen. This encouraging result is attributed to the function of CBA as filler which makes the concrete internal structure denser and more compact resulting in higher compressive strength. Similar positive trend has been reported by other researchers [15, 16] who added certain percentage of CBA as partial fine aggregate replacement in different types of concrete.

A decrease in compressive strength was observed as the percentage of sand replacement was more than 15%. This probably attributed to the characteristic of fine CBA possessing higher specific area than sand thus requires more water to coat the CBA particles. As a result, the concrete mix becomes drier, more difficult to mix and to compact when quantity of CBA used is increased. Finally, the concrete exhibits lower strength due to lack of bonding between particles and existence of more voids in the hardened concrete. Conclusively, integration of suitable percentage of CBA has enhanced the strength of OPS lightweight aggregate concrete.

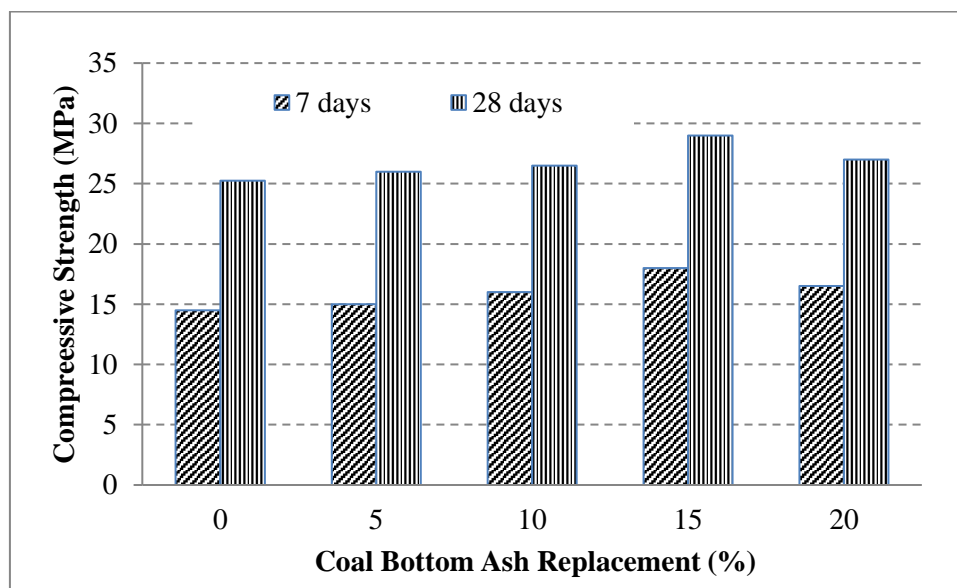


Figure 3. Compressive strength test result.

4. Conclusion

The finding shows that use of suitable amount of coal bottom ash able to produce oil palm shell lightweight aggregate concrete suitable for structural application. Integration of 15% of CBA produces concrete exhibiting the highest compressive strength value as compared to other mixes. This finding is expected to encourage the use of this waste material in lightweight concrete production and at the same time reduce the use of natural river sand.

Acknowledgments

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