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Properties of Hardened Concrete Containing CBA Ash and FCS as Partial Sand Replacement

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Abstract: A large amount of coal bottom ash (CBA) is being discharged from thermal power plants and has been making serious environmental pollution. Meanwhile, fine coconut shell (FCS) is an agricultural waste and is available in plentiful quantities throughout tropical countries worldwide. In many countries, coconut shell is subjected to open burning which contributes significantly to CO2 and methane emissions. Both of these materials are essential to utilize the CBA and FCS to reduce environmental pollution. Therefore, this study aims to determine the properties of combination of these materials as partial sand replacement. CBA is slow in pozzolanic activity of coal bottom ash which is suitable for partial replacement sand. Meanwhile, FCS is lightweight material with high density in porous filler. Concrete designed for 30 MPa strength at 28 days curing age and 0.50 of water-cement ratio in this study. The percentage of CBA used is 5%, 10%, 15% and 20%, while the percentage of FCS is 2%, 4%, 6% and 8% where it has been replaced by volume replacement. The specimens were cured in water for 7, 28, 56 and 90 days curing ages before compressive and splitting tensile strength test are conducted. It can be concluded that the density of the concrete decreased, compressive and splitting tensile strength show the improvement with the utilization of CBA and FCS in concrete. In addition, the percentage of water absorption increased as both of CBA and FCS absorb the water. This study shows that an optimum percentage of CBA found is 10% and FCS is 6% for this study.

Keywords: Concrete, Coal bottom ash, Fine coconut shell, Sand replacement

1. Introduction

The consumption of natural sand in concrete production is very high around the worldwide and it caused the shortage of natural fine aggregate which is suitable for construction in many countries (Rashad, 2016). This problem gives the chance for reuse by-products materials as a source of fine aggregate by partial or full replacement in construction activities (Irwan et al., 2014; Juki et al., 2013). Moreover, all over the world aimed at increasing the reuse and recycling suitable material for effective replacement of cement and fine aggregate in construction sector due to lack of natural resources (Azmi et al., 2018). CBA is a by-product produced from municipal solid waste incinerators and coal fueled power stations where it consists of 10mm to 15mm in size irregular particle. Moreover, CBA is an inert material and it can be used as aggregate for producing construction materials (Mazenan et al., 2017). The properties and particle size distribution of CBA is similar with river sand. This condition makes CBA suitable to be used as fine aggregate in the concrete production (Azmi et al., 2017). In the other hand, increasing amount of CBA disposed caused threat to environment and poses risk to human health. The hazardous constituents material in CBA can pollute the groundwater or surface water which lead to disturbing the ecosystem or living organisms (Singh & Siddique, 2017).

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Coconut has been a long time source of income for some people in country and there are various uses of coconut (Zamer et al., 2017; Gunasekaran et al., 2013). More than 60% of the domestic waste volumes are represent by coconut shell which presents serious disposal problems for local environment (Shahidan et al., 2017). Moreover, burning the agricultural waste lead to air pollution, soil erosion and decrease soil biological activity that can eventually decreased soil fertility (Zamer et al., 2017). Besides, coconut shell has high strength and modulus properties along with the added advantages of high lignin content other than it absorbs less moisture due to its cellulose content (Chanap, 2012). Therefore, this study aims to incorporating CBA and FCS as partial sand replacement materials in concrete. These combination of replacement materials will be promoted a way to produce friendly-waste materials and sustainable building.

2. Coal Bottom Ash and Fine Coconut Shell

Physical characteristics of CBA are porous surface texture, coarse, glassy, granular and grayish in color that collected from bottom of furnaces that burn coal (Mazenan et al, 2017; Singh & Siddique, 2013; Leman et al., 2017). The size of bottom ash is much coarser and containing significant voids from bubble compared to fly ash. Bottom ash show less pozzolanic activity as the particles have fused in the boiler. Hence, it is not suitable as an additive constituent in cement (Ghafoori & Buchole, 1997). However, CBA can be used as aggregates where its particles range in size from a fine gravel to a fine sand with very low percentages of silt-clay sized particles (Chun et al., 2013).

2.1 Properties of Coal Bottom Ash and Fine Coconut Shell

It is found that CBA have a similar particle size with sand and this result proved that CBA are suitable to be used as sand replacement in concrete (Rafieizonooz et al., 2016). The use of coconut shell can replace the existing material used in commercial product in order to reduce cost or improve mechanical properties of composite material (Anuar et al., 2017). Besides, coconut shell have high strength and modulus properties along with added advantages of high lignin content other than it absorbs less moisture due to its cellulose content (Chanap, 2012). The approximate value of coconut shell density is 1.60 g/cm3. The surface texture of coconut shell was fairly smooth on concave and rough on convex surfaces (Leman et al., 2017).

2.2 Preparation of Coal Bottom Ash and Fine Coconut Shell

CBA is collected at Tanjung Bin power plant in Pontian, Johor. CBA is used as partial fine aggregate replacement and tested on sieve analysis, fineness modulus and specific gravity to determine its physical properties. This material was dried in the oven for at least 24 hours. Then, CBA was screened to remove oversized particle and the material that pass 4.75 mm sieve as shown in Fig. 1 was used in this study. The replacement percentage of CBA that used in this study is 5%, 10%, 15% and 20%.

Fig. 1 - CBA after sieved.

Coconut shell that used in this study was collected from nearby local shop around the Parit Raja area. First, coconut shell was crushed into the smaller pieces with the size between 10 mm to 20 mm. Then, coconut shell was dried in the oven for 24 hours before it grinded in the milling jaw crusher until becoming smaller sizes. The process was continued by sieve FCS passed size of 4.75 mm to determine its selected size and used as partial sand replacement in concrete. Fig. 2 indicated the FCS after grinded and sieved. The replacement percentage of FCS that used in this study is 2%, 4%, 6% and 8%.

Fig. 2 - FCS after grinded.

The control mix of concrete was designed by referring to British Department of Environmental (DOE). Concrete designed to achieve 30 N/mm^2 at ages of 28 days and the slump range from 60 mm to 180 mm. The mix design of concrete was constructed according to the DOE with 0.5 of water-cement ratio. The replacement volume of CBA and FCS were calculated by volume replacement due to the CBA and FCS have lower specific gravity and it has a huge difference as compared to the sand.

The specimen for each mix proportion are made for compressive strength and splitting tensile strength tests. Then, the specimens were merged in curing tank water for 7, 28, 56 and 90 days for curing process. Compressive strength test was tested on 7, 28, 56 and 90 days while splitting tensile strength was tested only on 28 days curing age.

3. Properties of Hardened Concrete

3.1 Density

Density of concrete taken before compressive strength test was conducted. The weight of the concrete was divided with volume of specimen to determine the density. Fig. 3 shows the graph of density versus mixes of concrete.

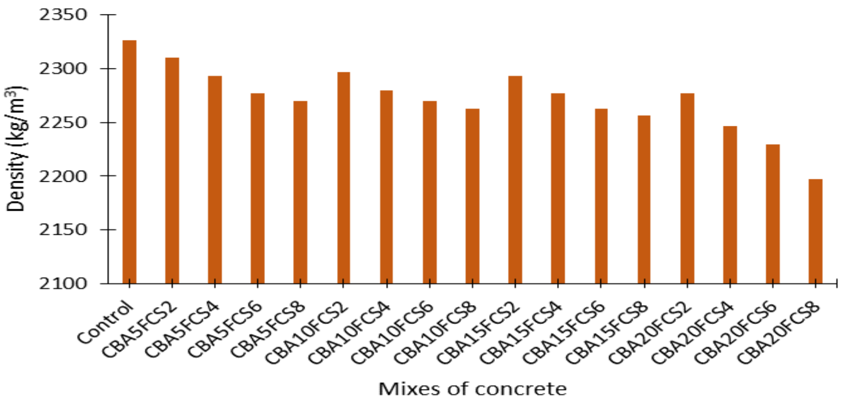

Fig. 3 - Density of concrete.

It is clearly shown that the density of concrete decreases with the increases of FCS as sand replacement. The same situation happened when the percentages of CBA increases in concrete. Highest density was recorded by control concrete which is 2327 kg/m^3. Meanwhile, the highest density of concrete containing both of CBA and FCS recorded by CBA5FCS2 which is 2310 kg/m^3 and only differs at 0.73% from control. In the other hand, CBA20FCS8 was lowest density that differs in 5.59% from control concrete where its density is 2197 kg/m^3.

The density of concrete decreased may be due to the specific gravity of CBA and FCS are lower than sand other than porous particles of CBA. The substitution of sand with CBA and FCS resulted in the replacement of heavy particles with lighter particles since specific gravity both of CBA and FCS are lower than sand (Wan Ibrahim et al., 2017). This situation increased the voids in concrete and hence lead to the lower density.

3.2 Compressive Strength

Compressive strength test is the method to determine the capacity of the material to withstand axially directed pushing force by using compression machine. This test was conducted on curing age of 7, 28, 56 and 90 days and its results are presented in Fig. 4.

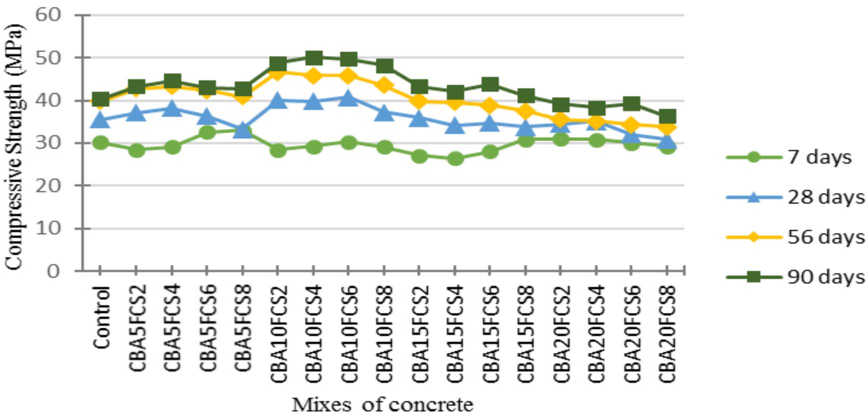

Fig. 4 - Compressive strength of concrete at curing age of 7, 28, 56 and 90 days

At 7 days of curing age, the strength of concrete shows an improvement with the utilization of CBA and FCS as partial sand replacement in concrete. Moreover, its strength increased with the increases of replacement percentage of FCS. The strength of concrete shows the increases with the replacement percentage of FCS up to 6% for CBA 5%. Further replacement percentage of FCS decreased the compressive strength of concrete at 7 days curing age. For the replacement of sand with CBA, strength of concrete increased with the utilization of CBA up to 10% in concrete.

The concrete containing CBA and FCS gained the strength of 28 days compressive strength as compared to 7 days strength. Up to 8% replacement percentage of FCS in concrete shows higher compressive strength compared to control specimen. In the other hand, up to 10% percentage of CBA as partial sand replacement in concrete shows the increment in their strength. Further replacement of CBA resulted lower strength compared to control specimen.

Concrete of CBA and FCS still shows the growth in strength until curing age of 56 and 90 days. However, concrete has slowed its growth in strength at 90 days curing age. All of mixes resulted in higher compressive strength as compared to control which only 40.4 MPa except for CBA20FCS8. Highest strength showed by CBA10FCS4 which 50.1 MPa. It may happen due to concrete have completed its hydration process as the formation of calcium silicate in cement hardened (Anuar et al., 2017; Mazenan et al., 2018).

3.3 Splitting Tensile Strength

Splitting tensile strength test is a method to determine tensile strength of concrete using cylinder which splits across the vertical diameter and it is an indirect method of testing tensile strength of concrete. Results in splitting tensile strength of control and concrete containing CBA and FCS are revealed in Fig. 5.

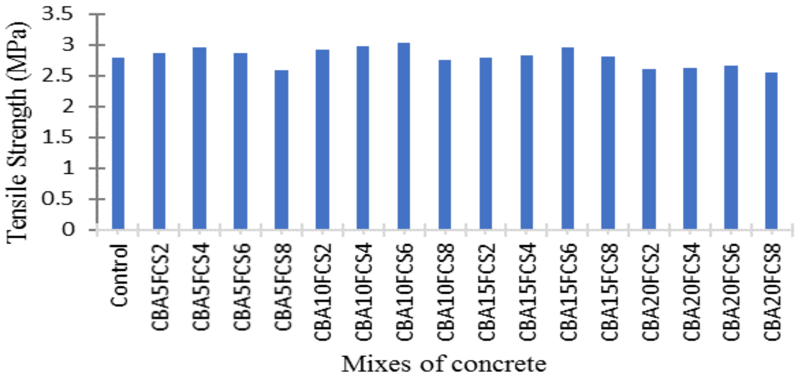

Fig. 5 - Splitting tensile strength of concrete.

It can be seen that tensile strength of concrete increased with the utilization of CBA and FCS as partial sand replacement. However, strength of concrete increased with the addition percentage of FCS up to 6% and further replacement shows the decrement in tensile strength with percentage of CBA 5%. For 10% replacement percentage of CBA, the strength also increased until 6% percentage of FCS where its strength was 3.03 MPa which is higher from control mix. Further replacement of CBA decreased the tensile strength. The lowest strength of tensile recorded by CBA20FCS8 with 2.56 MPa of tensile strength.

It may happen due to pozzolanic properties of CBA and FCS that improved the quality of paste hence resulted higher splitting tensile strength of concrete. The presence of pores by CBA and FCS in concrete probably helped block the spread of cracks thus increased the tensile strength of concrete. Small percentage of CBA and FCS in concrete lower the tensile strength might because the pores are low to prevent the spread of cracks.

4. Conclusion

As conclusion, the increasing replacement level of CBA and FCS decreased the density of concrete since both of the replacement materials had lower specific gravity than sand and the physical characteristic of materials itself is porous. In terms of compressive strength, it shows the improvement with the replacement of sand with CBA and FCS. The strength increased with the replacement level of CBA up to 10% and further replacement decreased the compressive strength. Besides, up to 6% replacement level of FCS increased compressive strength of concrete and further replacement shows the decrement in strength. Tensile strength of concrete increased with the utilization of CBA and FCS as partial sand replacement in concrete. Similar to compressive strength, further replacement of 10% CBA and 6% FCS decreased the tensile strength of concrete. The best optimum percentage of CBA 10% and the optimum percentage of FCS is 6%.

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