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Effect of Fly Ash as Partial Cement Replacement on Workability and Compressive Strength of Palm Oil Clinker Lightweight Concrete

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Effect of Fly Ash as Partial Cement Replacement on Workability and Compressive Strength of Palm Oil Clinker Lightweight Concrete

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Abstract. Environmental pollution caused by waste disposal namely palm oil clinker and fly ash from palm oil industry and coal power plant respectively needs to be resolved. The present investigation explores the influence of fly ash (FA) as partial cement replacement on workability, compressive strength and flexural strength of palm oil clinker lightweight aggregate concrete. A total of five types of mixes consisting 0%, 10%, 20%, 30% and 40% FA as cement replacement were used. All specimens were subjected to curing process by immersing it in water until the testing date. Concrete specimens were subjected to compressive strength and flexural strength test at 7 and 28 days. Incorporation of fly ash as partial cement replacement influences the fresh and hardened properties of this lightweight aggregate concrete. This novel finding shows that integration of up to 20% FA increases workability and contribute to strength enhancement of palm oil clinker lightweight aggregate concrete.

Keywords: palm oil clinker; lightweight concrete; fly ash; cement replacement; workability; compressive strength

1. Introduction

In the past few decades, sustainable green materials have been attracting worldwide attentiveness in construction and building material fields due to their ability to minimize the excavation of limestone for the cement industry. The rapid growth of housing and industrial building has also encouraged massive cement manufacturing, which has been one of the causes to the CO_2 emissions. The cement industry was estimated releasing approximately up to 7% of the global CO_2 production [1]. Therefore, it is crucial to use supplementary cementitious materials to mitigate the above-mentioned situation. Concurrently, the oil palm industry in Malaysia is expected to increase its dry solid biomass waste from 80 million tonnes in 2014 to 85-110 million tonnes by 2020 [4]. It produces various biomass waste by-products from the oil extraction process, such as fiber, mesocarp, kernel, nuts, oil palm fronds, oil palm clinker, and palm oil fuel ash [5]. The Palm Oil Clinker (POC) utilization has shown large numbers of benefits that facilitate the improvement of the mechanical properties of concrete [2, 3]. In general, POC is the final product from the combustion of palm oil shell and fiber. Furthermore, the POC waste has also been found fit to be used in production of lightweight concrete, apart from overcoming the waste disposal management [6]. In order to make the production of concrete more eco-friendly, the huge amount of coal fly ash (FA) produced from thermal power plants is a right combination with POC aggregate, which able to reduce the atmosphere pollution and disposal issues [7]. FA is a waste material that may generate problems of discarding as well as environmental degradation, due to its nature of causing air and water pollution on a large scale [8]. Incorporating this industrial waste as one of the ingredients in products creation would contribute to cleaner surrounding [9] through lesser fly ash waste disposal and lesser cement consumption in concrete production. So far, combination of FA as partial cement substitute manages to form concrete having good mechanical and durability performance [10]. The use of fly ash is limited up to 20% owing to variation in the fly ash characteristic which determined by its source and operation at power plant [11]. However, the potential of fly ash use in palm oil clinker lightweight aggregate concrete is unknown. Thus, the performance of palm oil clinker lightweight aggregate concrete in terms of fresh and hardened properties when fly ash is used as partial cement replacement remains to be investigated. Therefore, the objective of the current research was to investigate the effect of using FA as cement replacement materials on the concrete workability, compressive strength and flexural strength.

2. Experimental Work

2.1. Materials

Among the materials used for preparation of specimens in this research are sand, ordinary Portland cement, tap water, fly ash, high range water reducing admixture and palm oil clinker. Fly ash shown in Fig.1 was obtained from a coal power plant located in West Malaysia. This material is classified as pozzolanic Class F in accordance to ASTM C618 [12]. Palm oil clinkers were collected from trash dumping area in the vicinity of palm oil mill as illustrated in Fig. 2 and then transported to the laboratory. At the laboratory, the clinker chunks were cleaned and crushed into smaller size suitable to be used as coarse aggregate. Fig. 3 illustrates the physical appearance of clinker before and after processing ready for use.

Figure 1. Fly ash

Figure 2. Palm oil clinker gathering process

Figure 3. Palm oil clinker before and after processing

2.2. Mix Proportion
Five types of palm oil clinker lightweight aggregate concrete mixes were used. A control specimen of Grade 40 identified as FA0 were prepared by using 100% OPC as binder. The rest of mixes namely FA10, FA20, FA30 and FA40 were prepared by integrating diverse percentage of fly ash ranging from 10% to 40% as partial cement replacement. 1% superplasticizer was employed in all mixes. Other mixing ingredients used in those mixes were kept at constant quantity. The details of mix proportion used are tabulated in Table 1.

Table 1. Mix proportion of control specimen

Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	Clinker aggregate (kg/m^3)	Sand (kg/m^3)	Water (kg/m^3)
FA0	576	0	678	700	0.45
FA10	518	58	678	700	0.45
FA20	461	115	678	700	0.45
FA30	403	173	678	700	0.45
FA40	346	230	678	700	0.45

2.3. Sample Preparation and Testing
Prior to mixing process, all materials were measured accurately. The mixing tools and concrete mixer were ensured clean. Then, sand, cement, fly ash and clinker were mixed consistently in the mixer. After that, water and superplasticizer is added and mixed further to produce a homogenous mix. The fresh mix was subjected to slump test following the procedure in BS EN 12350 - 2 [13] to determine the mix workability. Then, the mix were filled in the mould cubes of 100x100x100mm and then compacted. After that, the moulds were covered with wet sack for 24 hours. The next day, the cubes were removed from the mould and then labeled before submerged in the water for curing process. The compressive strength test and flexural strength were conducted in accordance to BS EN 12390 – 2 [14] and BS EN 12390 - -5 [15] respectively. The preparation process of the specimens is illustrated in Fig. 4.

Figure 4. Specimen preparation work

3. Results and Discussion

3.1. Workability

The effect of fly ash (FA) as partial cement replacement on concrete workability is shown in Fig. 5. Plain palm oil clinker lightweight concrete mix demonstrates the lowest slump value. Inclusion of fly ash beginning from 10% replacement and further, forms mixture with enhanced workability. Incorporation of 40% fly ash produces the most workable mix of all with the highest slump value. The variation in slump pattern as the mix become more workable when larger content of fly ash is used can be observed in Fig. 6. The role of spherical form fly ash through its ball bearing influence permits improved mix workability [16].

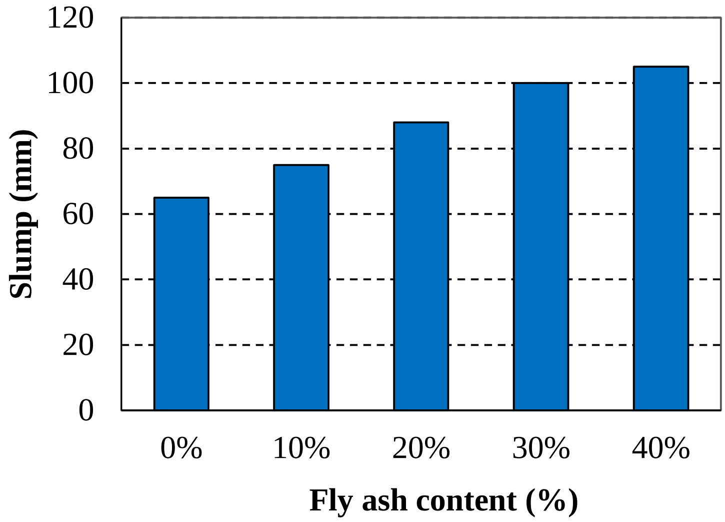

Figure 5. Effect of fly ash on workability of concrete

Figure 6. Effect fly ash on slump pattern

3.2. Compressive strength

Fig. 7 show the 28 days compressive strength of palm oil clinker lightweight concrete containing fly ash up to 40% as partial cement replacement is between 46MPa to 58MPa. In general, all specimen experience strength increment as curing age becomes longer owing to continuous presence of moisture resulting in uninterrupted chemical reactions for CSH gel formation. Incorporation of fly ash at 10% and 20% increases the concrete strength considerably which is about 24% and 22% respectively higher than control specimen. Concrete produced using 10% fly ash exhibit the highest compressive strength amongst all mixes. The contribution of pozzolanic reaction owing to the use of fly ash contributes to formation of additional CSH gel in concrete. As a result, better well packed concrete internal structure exhibit enhanced strength capacity. Incorporation of suitable content of pozzolanic ash would assist the concrete to achieve optimum strength [17]. However, the concrete strength declines when 30 and 40% of fly ash is integrated. Excessive use of pozzolanic material that reduces the quantity of cement content which limits the hydration process in the concrete mix. This causes generation of lesser calcium hydroxide which is required for occurrence of pozzolanic reaction thus reduces the total CSH gel resulting in weaker concrete. Past researchers [18] also observed the similar trend when different quantity of pozzolanic materials is incorporated as partial cement replacement in concrete.

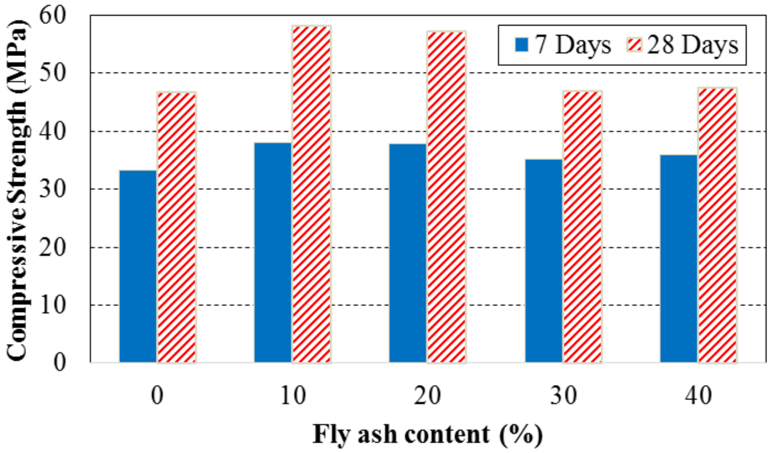

Figure 7. Compressive strength result

3.3. Flexural strength

Fig. 8 illustrates the flexural strength of palm oil clinker lightweight concrete containing fly ash at 7 and 28 days. The flexural strength of concrete grows with longer curing age from 7 days to 28 days. The highest flexural strength value is achieved when 10% fly ash is used in the concrete mix. Generally, the flexural strength result of the mix with diverse fly ash content, exhibit similar pattern as the compressive strength result.

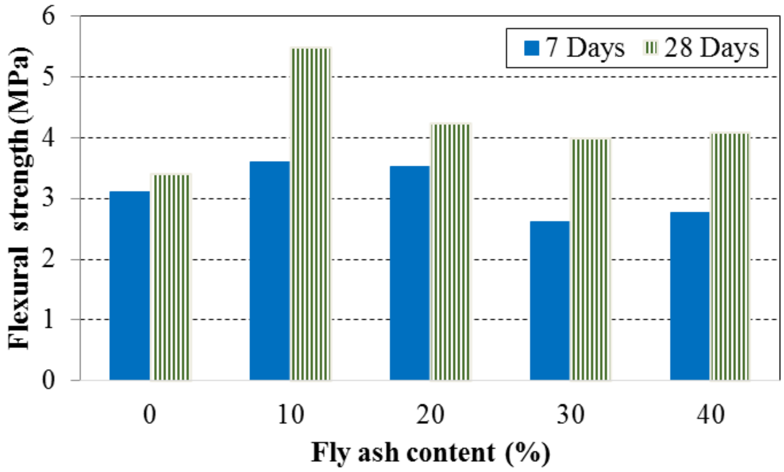

Figure 8. Flexural strength result

4. Conclusion

Utilization of 10% fly ash as partial cement replacement produces palm oil clinker lightweight aggregate concrete with the highest compressive strength and flexural strength of all mixes. Incorporation of fly ash in production of palm oil clinker lightweight concrete reduces the cement consumption resulting in more environmentally friendly concrete. Use of industrial wastes both palm oil clinker and fly ash would certainly lower the quantity of wastes disposed as well controls the use of natural resources from being consumed in concrete production.

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