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Flexural strength properties of porous concrete pavement incorporating nano black rice husk ash

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Abstract. Rice husk ash (RHA) as replacement material in the conventional concrete mixture has widely investigated around the world. However, there is a lack of study on nanoparticle produced from black rice husk ash (BRHA) used as a replacement material in porous concrete pavement mixture. Therefore, this study aims to evaluate the flexural strength properties of porous concrete pavement containing nano black rice husk ash. A nano BRHA dosage of 0, 10, 20, 30 and 40% by weight of binder used throughout the experiments. The total cementitious content used was 450 kg/m³ with a water/binder ratio of 0.34. It found that there appears to be an optimum replacement of approximately 10% nano BRHA, during which time the flexural strength and flexural activity index increase significantly.

1. Introduction

Malaysia has a tropical rainforest climate and rainfall throughout the year [1]. Due to the rapidly expanding built-up areas, more and more regions in Malaysia are paved. This will result in increased runoff and accumulation of water during heavy rainfall in the low-lying areas [2]. Conventional pavement, whether asphalt or concrete pavement, is designed with the purpose of preventing water from seeping to the soil through them [3]. If the storm-water runoff cannot control, flooding will occur. Various methods have used in order to mitigate flooding [4]. During heavy rainfall, there is a lot of water splash and spray on the road due to vehicles hitting the accumulated water [5]. The water splash and spray is well known as one of the accident causes on the road during the rainfall season. Over the years, developed countries have started to use the porous concrete pavement as a solution for a storm-water runoff on the road pavement. In addition to its characteristic of allowing water through its structure, the porous concrete pavement has the capacity to absorb noise generated from vehicles and other sources. Porous concrete has become increasingly used in a variety of infrastructures, pavements and overlays subjected to heavy traffic load. Due to these extended applications, superior strength and durability constitute the main concerns associated with porous concrete [6]. On the other hand, the nanoparticle is one of the options in order to improve the strength loss in the porous concrete pavement.



In order to study the performance of using nano black rice husk ash (BRHA), the objective has been set to investigate the flexural strength properties of porous concrete pavement containing nanoparticle from black rice husk ash.

2. Materials and method

2.1. OPC and aggregate

The major binder material used in this study was ordinary Portland cement (OPC) Type I. The cement used was supplied by Tasek Corporation Malaysia in one batch for the entire experimental works. According to Abd Halim et al. [7], the chemical composition of the OPC was within the standard range of 70% CaO, 17.8% SiO₂, 3.9% Al₂O₃, 3.2% Fe₂O₃, 1.5% MgO, and 3.6% SO₃. The OPC similarly indicated a compound composition of 54.5% C₃S, 18.2% C₂S, 9.4% C₃A, and 10.5% C₄AF. The crushed granites aggregates supplied by Hanson Quarry were used in the production of porous concrete pavement mixtures. The aggregates were graded in the range of 12.5 mm to 4.75 mm nominal size. It has a specific gravity of 2.71, water absorption (0.83%) and aggregates impact value (17%). However, the fine aggregate was eliminated in this investigation.

2.2. Nano BRHA

Nanoparticle was produced from the black rice husk ash (BRHA). The black rice husk ash was ground using laboratory ball mill grinder. The mean particle size of nano used in this study is 66 nm. SiO₂ was identified as the main component of the BRHA. In addition, SiO₂, Al₂O₃, and Fe₂O₃ comprised 93.48% of the material, in accordance with ASTM C618-17a [8], which requires that these three main oxides should comprise no less than 70% of the pozzolanic material.

2.3. Mix proportions and curing

The specimens were prepared with four different percentage of nano BRHA replacement namely 0%, 10%, 20% and 30%. A 0% nano BRHA indicated as a control specimen. The specimens were tested at three curing days, i.e. 7 days, 28 days and 90 days. At the laboratory, the aggregates, OPC and nano BRHA were first mixed for 1 minute under dry condition. The water was then added to the drum mixer, and the mixing was performed for another 3 minutes. Then the mixture was cast in the steel mould. The specimens were cast in two layers and compacted using a bearing plate and Proctor hammer. Immediately after casting process, the specimens were kept and cover by wet hessian to avoid moisture loss.

2.4. Mix proportions and curing

The flexural strength test was conducted to evaluate the resistance of concrete to bending deflection. This test was conducted according to British standard BS EN 12390-5 [9]. The loading rate of 0.4kN/s was applied during the test. The prism porous concrete specimens (100 mm height x 100 mm width x 500 mm length) were used for this testing.

3. Results and discussion

3.1. Flexural strength

The result for flexural strength with different percentages of nano BRHA replacements was shown in Figure 1. It can be seen that the highest strength for 7, 28 and 90 days age (10% nano BRHA) is 3.70 MPa, 4.43 MPa and 4.85 MPa respectively, where the lowest strength for 7, 28 and 90 days age (30% nano BRHA) is 2.92 MPa, 3.98 Mpa and 4.37 Mpa respectively. As shown in the figure, the strength starts to increase from 0% to 10% nano BRHA replacement, then decrease from 10% to 20% nano BRHA replacement. The same applies to 20% to 30% nano BRHA replacement; the flexural strength continues to decrease. According to Mohd Ibrahim et al. [10], the best pozzolanic reaction between Ca(OH)₂ and nano BRHA occurs when 10% nano BRHA is replaced in the mixture. The amount of

Ca(OH)_2 contained in the mixture is enough to react with 10% nano BRHA to produce calcium silicate hydrate (CSH). This CSH directly strengthens the structural bonding and results in the highest flexural strength compared to others [11]. The excessive nano BRHA replacement in the mixture possibly will result in an inadequate pozzolanic reaction to increase the strength [12]. The amount of Ca(OH)_2 maybe not enough to react with more than 20% nano BRHA replacement to produce more CSH to strengthen the internal structure bonding. For all percentages replacement, the flexural strength with 10% and 20% nano BRHA is higher than the controlled specimen. Although both specimens with 10% and 20% nano BRHA replacement have a higher flexural strength than the control specimen, the best property for flexural strength is 10% nano BRHA. It is because specimens with 10% nano BRHA replacement have the highest flexural strength compared to others.

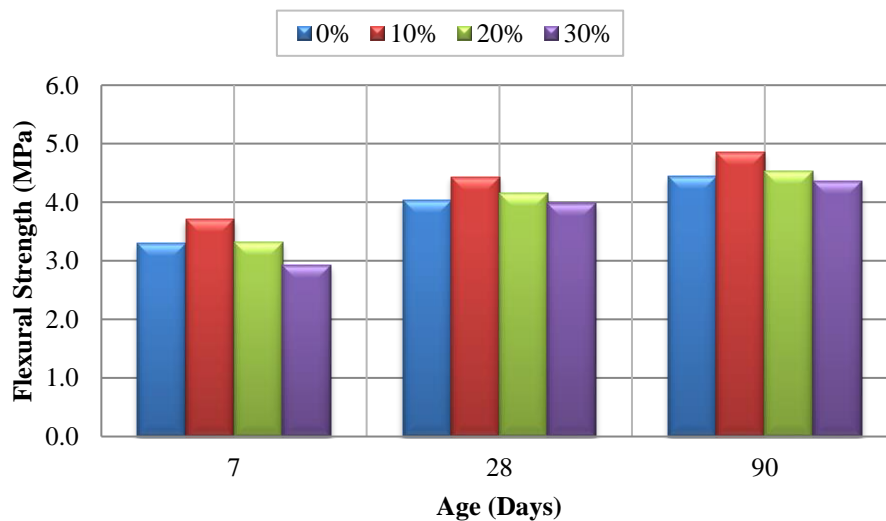


Figure 1. Flexural strength of porous concrete pavement at varying nano BRHA

3.2. Flexural strength and curing age

The relationships between flexural strength and the age of the specimens are shown in Figure 2. All the trend lines show an increase from 7 days to 90 days specimen age. The flexural strength for all percentages of nano BRHA replacement shows an increase with the increase in the specimen's age. This is because of the hydration process in the specimens [13]. The increasing time in the hydration process will increase flexural strength. The R-square value of the relationship between flexural strength and the age of the specimens are listed in Table 1. It can be seen that the flexural strength has a good relationship with the age of the specimens with the R² values for the 0%, 10%, 20% and 30% of the nano BRHA replacement are 0.8163, 0.823, 0.7715 and 0.7354, respectively.

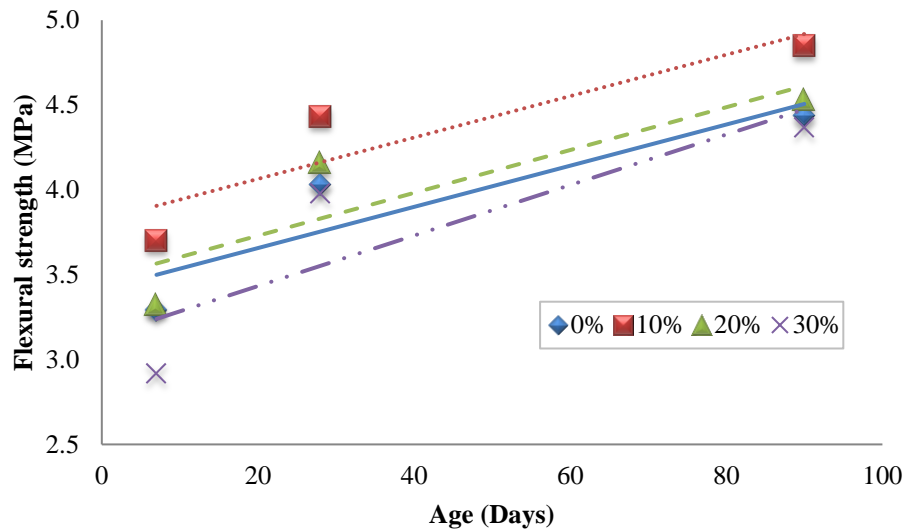


Figure 2. Flexural strength vs curing age

Table 1. R² value flexural strength vs. age of specimens

Nano BRHA (%)	(0%)	10%	20%	30%
R ²	0.8163	0.823	0.7715	0.7354

3.3. Flexural strength and activity index

The flexural strength activity index is shown in Figure 3. It can be seen that the highest strength activity index at all ages is for a specimen with 10% nano BRHA replacement. The strength activity index is 112% (7d), 110 (28d) and 109 (90d). The lowest strength activity index is a specimen with 30% nano BRHA replacement. The strength activity index is 89% (7d), 99% (28d) and 98% (90d). The results also found that the specimen with 20% nano BRHA replacement has the strength activity index more than 100%. It can be said that the strength activity index decreases with the increase in the nano BRHA replacement. It is possibly due to the excessive amount of nano BRHA replacement in the specimens. The increase in the percentage nano BRHA replacement will decrease the cement amount in the mixtures. Indirectly it will decrease the amount of Ca(OH)₂ in the specimens. The lack of Ca(OH)₂ in the specimens will decrease the pozzolanic reaction in the specimens. In consequence, it decreases the strength activity index for the specimens. Previously Gemma [14] found that using rice husk ash (RHA) results in a significant improvement in the flexural strength of concrete. The nano BRHA used in this study are produced from BRHA which is similar as RHA. In general, the strength activity index for all specimens exceeds 75%.

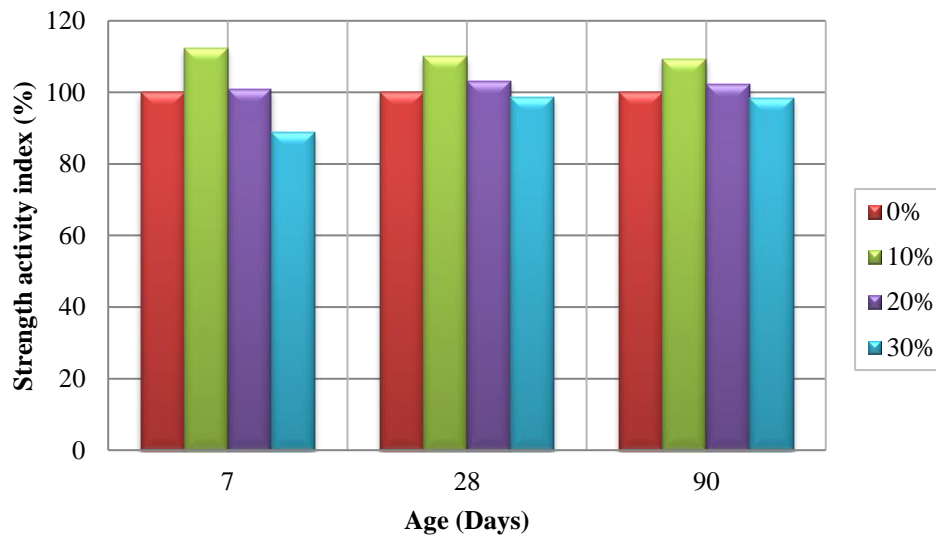


Figure 3. Flexural strength activity index

4. Conclusions

- The use of 10% nano BRHA as a cement replacement in porous concrete pavement resulted in good flexural strength development in comparison with the other nano BRHAs level. Nano BRHA has high potential to develop porous concrete pavement with superior flexural strength value.
- There appears to be an optimum nano BRHA replacement of 10%, for which the strength activity index increased significantly.
- In general, the flexural strength of nano BRHA percentage shows an increase with the increase in the curing age due to the hydration process in the porous concrete pavement.

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