Effect of Nano Silica on the Physical Property of Porous Concrete Pavement

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Abstract. Rice husk can be categorized as an organic waste material from paddy industries. Silica is a major inorganic element of the rice husk. The aim of present study is to evaluate the effect of Nano silica on the physical properties of porous concrete pavement. Rice husk has been burned in the furnace (650°C for 6 hours) and ground for four different grinding times (33, 48, 63 and 81 hours). Five types of mixes were prepared to evaluate the different Nano silica grinding time. A Nano silica dosage of 10% by weight of binder was used throughout the experiments. The physical properties were examined through compressive strength, transmission electron microscopy and x-ray fluorescence. The experimental results indicate that the different Nano size gives a different effect to porous concrete strength. Based on the results obtained, Nano silica ground for 63 hours (65.84nm) gives the best result and performance to porous concrete pavement specimens.

1. Introduction

Rice is the agriculture product produced from paddy. The husking process of paddy produced waste called rice husk. Paddy on average comprises of 20-22% rice husk [1]. Ramadhansyah et al. [2] found that the major inorganic element in the rice husk is silica. Through the certain process (burning and milling), silica from rice husk will be extracted and produced Nano silica (NS). This material can be produced with varying pozzolanic activity index depending on the degree of grinding and burning temperature [3]. The result obtained from previous researchers shows that the optimal of rice husk ash (RHA) replacement ranged from 10 - 20% [3-5]. The good pozzolanic reaction in cementitious mixture makes NS popular in concrete research and industries [6]. Thus, the aim of this study is to determine the optimum grinding time of NS with respect to the concrete property. The effect of grinding time on the physical property of NS also investigated.

2. Materials and Methods

2.1. Raw materials

Type I ordinary Portland cement was used in this investigation. According to Jayanti et al. [7], the chemical composition of ordinary Portland cement was within the standard range, with 70% calcium oxide, 17.8% silicon dioxide, 3.9% aluminium oxide, 3.2% iron oxide, 1.5% magnesium oxide and 3.6% sulfur trioxide. In addition, crushed granite of nominal size 12.5 mm was used as the coarse aggregate in the concrete mixtures. The coarse aggregate had a specific gravity of 2.69 and water absorption of 0.83%.
2.2. Grinding procedure
According to Jaya et al. [8], rice husk was burnt at 650°C for 6 hours in an electric furnace at a heating rate of 10°C/min. The RHA was left to cool inside the furnace and removed the next day. 500 grams of RHA was placed in the drum and ground with grinding media (Table 1) to produced NS. The NS samples were then subjected to X-ray fluorescence (XRF) analysis and transmission electron microscopy (TEM).

Table 1. Grinding media

| Drum (Steel)       | 200mm dia. x 230mm height |
|-------------------|---------------------------|
| Balls (Steel)      | Diameter mm | Amount |
| 25                |             | 7      |
| 20                |             | 17     |
| 16                |             | 18     |
| 12                |             | 18     |
| Rods (Steel)       | Diameter x Length (mm) | Amount |
| 9.5 x 220         |             | 2      |
| Milling speed      |             | 60 rev/min |

2.3. X-ray Fluorescence (XRF)
XRF is a simple method of testing and well known as non-destructive method for qualitative and quantitative analysis of elemental composition in a wide range of materials. According to BS EN ISO 12677 [9], a 10 g sample in dried powder form (passing a 45 µm sieve) was compacted by pressing the sample into a 35 mm diameter pellet at a load of 20 tonnes for 10 seconds. The sample was characterized using RIGAKU RIX3000 wavelength XRF.

2.4. Transmission electron microscope (TEM)
TEM Hitachi HT7700 was used to visualize and analyze the Nano sized RHA. This instrument can be used to measure the sample in the microscale (1µm) to nanoscale (1nm). TEM can analyze the sample with high-image resolution and magnification.

2.5. Mix proportions and curing
The OPC was partially replaced with nano silica from RHA (NS) at a dosage of 10% by weight of cementitious material. The mixes were designed to achieve concrete of grade 20 N/mm² at 28 days. A water-to-cement ratio of 0.34 was used. Specimens were cast in two layers and were compacted using proctor hammer (5 blows per layer). After casting, the moulded specimens were covered with wet hessian for 24 hours to avoid evaporation. The specimens were demoulded on the following day and then placed in the polyethylene bag for curing until the time of testing. The mix proportions are shown in Table 2. The 33 h ground was generally designated as NS1, 48 h (NS2), 63 h (NS3) and 81 h (NS4), accordingly.
Table 2. Mixture Proportions

| Materials | Mixture Proportions (kg/m³) |
|-----------|----------------------------|
|           | Control | NS1 | NS2 | NS3 | NS4 |
| W/C       | 0.34    | 0.34| 0.34| 0.34| 0.34|
| Aggregate | 1115    | 1115| 1115| 1115| 1115|
| Water     | 153     | 153 | 153 | 153 | 153 |
| Cement    | 450     | 405 | 405 | 405 | 405 |
| NS        | 0       | 45  | 45  | 45  | 45  |

2.6. Compressive strength test
Compressive strength test was carried out on concrete cubes of size 100x100x100 mm. The test was conducted according to the British standard test method [10]. The specimens were tested for compressive strength using MATEST compression testing machine at a rate of loading of 3.5kN/s. The strength of three samples was averaged and reported.

3. Results and Discussion
3.1. Effect of grinding time
The RHA was ground for 33, 48, 63 and 81 hours and designated as NS1, NS2, NS3 and NS4 respectively. The particle size of ground NSs were measured by using TEM analysis. It was found that the mean particle size of NS1, NS2, NS3 and NS4 are 85.42nm, 78.77nm, 65.84nm and 64.26nm, respectively. The results from TEM analysis clearly shows that the mean particle size of NSs decreases with increased grinding time.

3.2. Chemical composition
The chemical composition of the NS was analyzed by x-ray fluorescence (XRF) and the results are shown in Table 3. According to ASTM C618 [11] standard specification for natural pozzolan for use in concrete, the minimum percentage of SiO₂ + Al₂O₃ + Fe₂O₃ is 70% and the maximum of SO₃ is 4%. From the XRF result, it was found that the percentage of SiO₂ + Al₂O₃ + Fe₂O₃ and SO₃ are 83.27% and 0.96% respectively which mean it meets the requirement for use in concrete.

Table 3. Chemical Composition of NS

| Constituent | SiO₂ | Al₂O₃ | Fe₂O₃ | C | SO₃ | K₂O | P₂O₅ | CaO | etc. |
|-------------|------|-------|-------|---|-----|-----|------|-----|------|
| Percentage  | 82.64| 0.17  | 0.46  | 4.06| 0.96| 5.97| 2.02 | 1.07| 2.65 |

3.3. Compressive strength
Compressive strength is commonly considered as the most important property of concrete to give an overall picture of its quality and performance. As shown in Figure 1, the compressive strength at 7 and 28 days for NS3 is the higher between four porous concrete mixes containing NS but slightly lower than control mix. The compressive strength of the porous concrete mixes was in the range of 8.38 – 16.12 N/mm² (7 days) and 12.49 – 21.18 N/mm² (28 days). The higher strength of NS3 between four porous concrete mixes containing NS is probably due to the fineness of the particles, the irregular particle shape and the filler effect that gives the best pozzolanic reaction to the porous concrete mixture.
Figure 1. Compressive strength at 7-d and 28-d

3.4. **Strength activity index**

Figure 2 illustrates the effect of grinding time on the strength activity index. The strength activity indices increased with increasing grinding time for NS. The highest strength activity indices at 7 and 28 days between four concrete mixes containing NS is 89.09% and 89.68% respectively. It was obtained using NS3 subject to 63 hours grinding time. When the grinding time was increased from 63 hours to 81 hours (NS4), there was a slightly dropped in strength activity index compared to NS3. This is may be due to higher water demand because of the high specific surface area of the NS1. Based on these results, it appears that the optimum grinding time for NS is approximately 63 hours. According to ASTM C311/C311M [12], the minimum strength activity index for natural pozzolan compared to OPC is 75% which means by using NS3, its meet the physical requirement of natural pozzolan for use in concrete.

Figure 2. Strength activity index at 7-d and 28-d

4. **Conclusions**

Based on this study, the following conclusions can be drawn:

a. The mean particle size of NS decreased with increased grinding time.

b. The use of NS3 (ground for 63 hours – mean particle size of 65.84nm) in porous concrete mix resulted in good strength development compared to other NSs ground with different grinding times.

c. The strength activity index of porous concrete containing NS increased with increased grinding time.

d. The optimum grinding time of NS approximately 63 hours for the best compressive strength and strength activity index.
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