IOP Conf. Series: Materials Science and Engineering **290** (2018) 012050 doi:10.1088/1757-899X/290/1/012050

Mechanical performance of porous concrete pavement containing nano black rice husk ash

M Y Mohd Ibrahim[1], P J Ramadhansyah[1], H Mohd Rosli[1] and M H Wan Ibrahim[2]

[1]Faculty of Civil Engineering, Department of Geotechnics and Transportation, Universiti Teknologi Malaysia, 81310 UTM, Johor Bahru, Malaysia
[2]Faculty of Civil and Environmental Engineering, Department of Material and Structure Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia

Email:ramadhansyah@utm.my

Abstract. This paper presents an experimental research on the performance of nano black rice husk ash on the porous concrete pavement properties. The performance of the porous concrete pavement mixtures was investigated based on their compressive strength, flexural strength, and splitting tensile strength. The results indicated that using nano material from black rice husk ash improved the mechanical properties of porous concrete pavement. In addition, the result of compressive, flexural, and splitting tensile strength was increased with increasing in curing age. Finally, porous concrete pavement with 10% replacement levels exhibited an excellent performance with good strength compared to others.

1. Introduction

Porous concrete pavement also known as a pervious or permeable concrete pavement and it has been used to control storm water runoff in road pavement and others applications. According to the previous study, the high content of voids in porous concrete lowers the ability to get the high strength [1], [2]. It also found in previous researches that the increasing in void percentages will decrease the strength of hardened concrete [3]-[5]. Mohd Ibrahim et al. [6] found in their literature that, Nano silica is one of the options in order to improve the strength loss in the porous concrete. By incorporating Nano silica in the mixture, it can increase the compressive strength of hardened cement paste and bond strengths of paste-aggregate interface [7]. As the major constituent of rice husk ash is silica, the Nano silica produced from black rice husk ash has been used in this study. In order to study the performance of using nano black rice husk ash, the objective has been set to investigate and to determine the optimum percentage of nano silica from black rice husk ash as a cement replacement in porous concrete specimens in term of mechanical engineering properties. Therefore, the compressive strength, tensile splitting strength, and flexural strength of the porous concrete specimens were examined.

IOP Conf. Series: Materials Science and Engineering **290** (2018) 012050 doi:10.1088/1757-899X/290/1/012050

2. Materials

2.1 Cement
Type I ordinary Portland cement (OPC) was used as the major binder material in this study. The cement used was supplied by Tasek Corporation Sdn. Bhd. in one batch for the entire experimental works. The chemical composition of the OPC was given in Table 1. The mean particle size of the OPC is 1353 nm.

2.2 Coarse aggregates
In this study, crushed granites were used as the aggregates source to include in the specimens mixtures. The aggregates were supplied by Hanson Quarry Product Sdn. Bhd. As the porous concrete specimen has little or no fine aggregates, only coarse aggregate used in this study. 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 of 0.83%, and aggregates impact value was about 17%.

2.3 Nano black rice husk ash
Nano material was produced from the black rice husk ash. 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. Table 1 shows the chemical composition of the black rice husk ash.

Table 1. The chemical composition of the OPC and nano silica.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3
OPC	22.68	4.72	3.5	62.27	1.89	-	0.31	4.29
BRHA	91.33	0.07	0.07	0.45	0.28	0.01	2.64	0.05

3. Experimental Procedures

3.1 Sample preparation
A control mix was prepared using OPC. Nano silica replacement levels of 10%, 20%, 30% and 40% by weight of cement were applied. Table 2 shows the mix proportion used in this study. In order to mix the porous concrete mixture, all the materials were placed into drum mixer in the following order: coarse aggregate and binder (OPC or blended cement). The materials were first mixed for 1 minute under dry condition. The water was then added into drum mixer and the mixing was performed for another 3 minutes. Then the mixture was casted in the steel mould. The specimen for compressive strength test, splitting tensile strength test and flexural strength test were casted in the cube (100 mm x 100 mm x 100 mm) steel mould, cylinder (100 mm diameter x 200 mm length) steel mould and prism (100 mm height x 100 mm width x 500 mm length) steel mould respectively. The specimens were casted 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.

Table 2. Mix proportions of porous concrete pavement containing nano black RHA

Nano replacement (%)	w/c	Water (kg/m^3)	Cement (kg/m^3)	Nano (kg/m^3)	Coarse Aggregate (kg/m^3)
0 (OPC)	0.34	153	450	0	1115
10	0.34	153	405	45	1115

20	0.34	153	360	90	1115
30	0.34	153	315	135	1115
40	0.34	153	270	180	1115

3.2 Curing condition
According to Mohd Ibrahim et al. [8], the curing condition followed BS1881-113:2011 [9] is the best option for porous concrete specimens. In this study, the curing condition as per BS 1881 – 113:2011 [9] has been selected. After demoulding the specimens, it was then immersed in the water. The specimens were drained and immediately placed in the polyethylene bag. Lastly, the polyethylene bag was seal and store until the testing date.

3.3 Compressive strength test
Compressive strength can be considered as the main property of concrete. In this study, the compressive strength test was conducted on 100 x 100 x 100 mm cube specimens. The specimens were compressed using MATEST compression strength test machine. The specimens were compressed with a loading rate of 3.5kN/s. The test was conducted according to the British standard test method BS EN 12390-3:2002 [10].

3.4 Tensile splitting strength test
Splitting tensile strength test on the concrete cylinder is a method to determine the tensile strength of the concrete. The test was carried out followed the British standard test method BS EN 12390-6:2009 [11], using cylindrical specimens of 200 mm length x 100 mm diameter. The specimens were compressed with a loading rate of 2.5kN/s.

3.5 Flexural strength test
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 12390-5:2009 [12]. 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.

4. Results and discussions

4.1 Compressive strength
The compressive strength of the concrete is one of the most important factors and it's usually used to judge the concrete quality [13]. Figure 1 shows the result of compressive strength for the various nano replacements. Generally, the compressive strength for all specimens increases with increasing in curing age. From the figure, it can be seen that the highest compressive strength at all ages is 10% replacement specimen which is 20.88 MPa, 24.45 MPa, 27.80 MPa, 34.20 MPa and 35.23 MPa for 7, 14, 28, 56 and 90 days respectively. The 40% replacement of NS is the lowest compressive strength which is 14.64 MPa, 16.28 MPa, 22.92 MPa, 27.53 MPa and 29.30 MPa for 7, 14, 28, 56 and 90 days respectively. As shown in the figure, the only specimen with 10% of nano replacement has the strength more than control specimens. Compared to strength with control specimens, the strength of specimens with 10% nano replacement increased 5.14%, 4.01%, 9.08%, 5.10% and 3.94% for 7 days, 14 days, 28 days, 56 days and 90 days respectively. The compressive strength for the each day of testing shows the same trend where the compressive strength starts to increase from 0 % replacement to 10 % replacement of nano. The compressive strength starts to decrease from 10 % to 20% replacement of nano. Same goes to 20 % to 30 % and 30 % to 40 % replacement. This finding similar to Siddharth et al. [14] where the compressive strength start to increase with 10% replacement and it is starting to decrease when the replacement beyond than 10%. This

phenomenon happened probably due to workability and the lack of required water in the mixture. From this figure, the 10 % replacement of nano has the best property for the compressive strength evaluation.

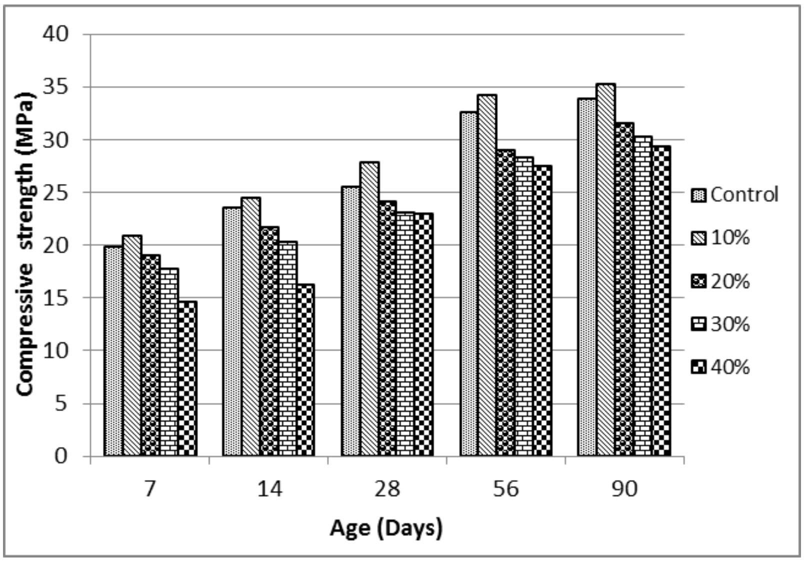

Figure 1. Compressive strength of porous concrete pavement

4.2 Tensile splitting strength

Figure 2 shows the results of tensile splitting strength for porous concrete specimens with different nano percentage replacement. The highest strength at 7, 14, 28, 56 and 90 days are 10% nano replacement which is 3.68 MPa, 3.75 MPa, 4.28 MPa, 4.57 MPa and 4.79 MPa respectively. However, the lowest strength at all age is at 40% nano replacement. The strength for 40% nano replacement is 1.67 MPa, 1.95 MPa, 2.49 MPa, 2.81 MPa and 2.93 MPa respectively. Generally, the strength starts to increase from 0% nano replacement to 10% nano replacement. Then, the strength starts to decrease at 20% nano. Same goes to 30% and 40% nano replacement, the strength continues to decrease. The result also shows that only specimen with 10% nano replacement has the strength more than control specimen. The strength of the specimens increased 11.98%, 10.63%, 8.26%, 10.56% and 11.14% at all ages respectively. The strength for specimens with 20%, 30% and 40% nano has strength below than control specimen. From the results obtained, the specimen with 10% nano replacement has the best property for the tensile splitting strength evaluation. This finding similar to Akeke et al. [15] where 10% is the optimum percentage of replacement.

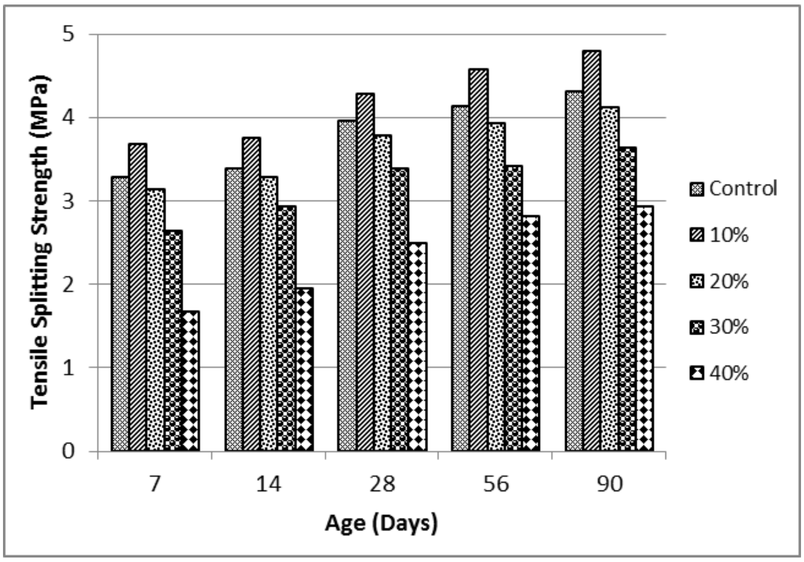

Figure 2. Tensile splitting strength of porous concrete pavement.

4.3 Relationship between compressive strength and tensile splitting strength

An overview of the relationship between compressive strength versus the tensile splitting strength of various percentage of nano replacement is presented in Figure 3, while Table 3 shows the R^2 value for each relationship. As reflected in Figure 3, the tensile splitting strength increased with the increase of compressive strength. As shown in Table 3, R^2 value for 7 days, 14 days, 28 days, 56 days and 90 days are 0.9948, 0.9739, 0.6732, 0.8142 and 0.8936 respectively. Among others, the R^2 value for 28 days specimens shows the lowest which is 0.6732. However, as presented in Figure 2, the graph still shows that the tensile splitting strength increased with the increase of compressive strength.

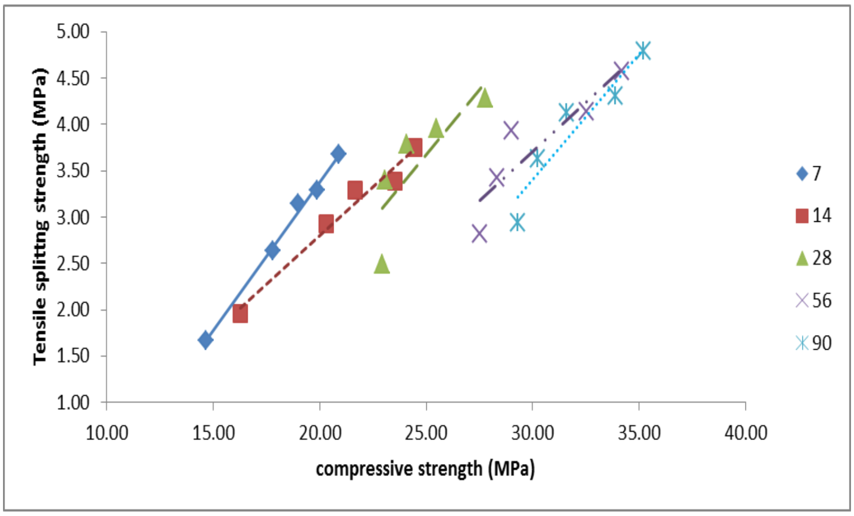

Figure 3. Relationship between compressive and tensile splitting strength.

Table 3. Coefficient of relationship between compressive and tensile splitting strength.

Age (days)	7	14	28	56	90

R^2	0.9948	0.9739	0.6732	0.8142	0.8936

4.4 Flexural strength

The result of flexural strength with different percentage of nano replacement was shown in Figure 4. It can be seen that the highest strength for 7 days, 28 days and 90 days age are specimens with 10% nano replacement which is 3.70 MPa, 4.43 MPa and 4.85 MPa respectively. Compared to control specimens, the strength for 10% nano replacement specimens increased 12.45%, 10.01% and 9.32% for 7 days, 28 days and 90 days respectively. The lowest strength for 7 days, 28 days and 90 days age are specimens with 30% nano replacement which is 2.92 MPa, 3.98 MPa and 4.37 MPa respectively. As shown in the figure, the strength starts to increase from 0% nano replacement to 10% nano replacement. The strength starts to decrease from 10% to 20% nano replacement. Same goes to 20% to 30% nano replacement, the strength continues to decrease. For all percentage nano replacement, the strength with 10% and 20% nano replacement has the strength higher than control specimen strength. It is different from compressive strength and tensile splitting strength that only 10% nano replacement specimens have strength higher than control specimens. Wang et al. [16] mentioned that NS had smaller particles and it can fill between cement particles, therefore the density of the cement paste increased. The presence of NS gives an improvement of the bond between the cement matrix and aggregate, resulting in an improvement in flexural strength. Although both specimens with 10% and 20% nano replacement has the strength higher than control specimen, the best property for flexural strength is specimens with 10% nano replacement. It is because, specimens with 10% nano replacement has the highest flexural strength compared to others.

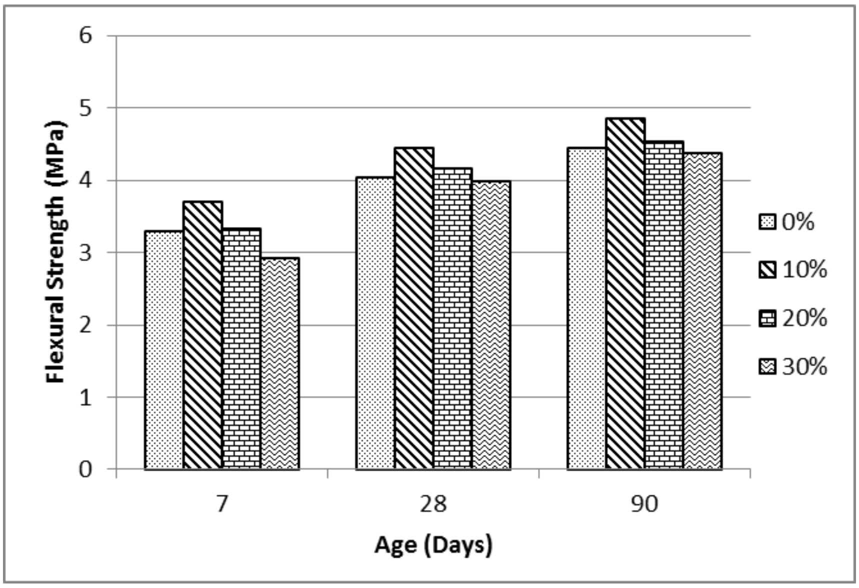

Figure 4 Flexural strength of porous concrete pavement

Figure 5 illustrated the relationship between compressive strength and flexural strength. From this graph, it can be seen that not all flexural strength increase proportionally with the increase in compressive strength. The graph shows that, the compressive strength of 20 % nano replacement lower than the control specimen. However, for the flexural strength, the specimen with 20 % nano replacement shows higher strength than control specimen. As reported by Ramadhansyah et al. [17], the advantages of using rice husk ash include increased in flexural strength. These phenomena happened at all age. It is obviously seen at 90 days age of specimen's relationship graph. Table 4 shows the R^2 value for the relationship between compressive strength and flexural strength. The R^2 value for 7, 28 and 90 days age is 0.9038, 0.7113 and 0.5826 respectively. The R^2 value for 90 days age is low due to phenomena as mentioned before.

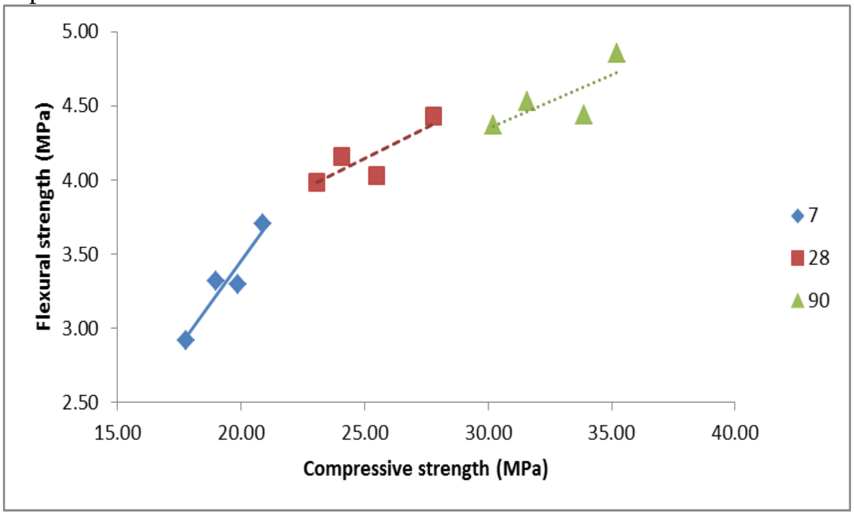

Figure 5 Relationship between compressive and flexural strength

Table 4 Coefficient of relationship between compressive and flexural strength

Age (days)	7	28	90
R^2	0.9038	0.7113	0.5826

5. Conclusion

The performances of nano from black rice husk ash as cement replacement on the mechanical properties of porous concrete pavement were investigated in this study. Results showed that the use of nano black rice husk ash in porous concrete pavements resulted in good compressive strength, tensile splitting strength, and flexural strength compared with the controlled specimen. Furthermore, 10% replacement of nano black rice husk ash to be found as an optimum replacement and indicated better performance than other mixtures.

Acknowledgement

The support provided by Malaysian Ministry of Higher Education and Universiti Teknologi Malaysia in the form of a research grant vote no. Q.J130000.2522.18H05 for this study is highly appreciated.

References

[1] Ramadhansyah P J, Mohd Ibrahim M Y, Mohd Rosli H and Wan Ibrahim M H 2014 *Appl Mech Mater* **554** 37-41
[2] Mohd Ibrahim M Y, Ramadhansyah P J, Mohd Rosli H, Wan Ibrahim M H 2014*Advanced Review on Scientific Research* **1(1)** 34-42
[3] Aamer Rafique Bhutta M, Tsuruta K, Mirza J 2012 *Constr Build Mater* **31** 67-73
[4] Kim H K and Lee H K 2010 *Appl. Acoust.* **71(7)** 607-615
[5] Pindado M A, Aguado A, Josa A 1999 *Cem. Concr.* **29(7)** 1077-1083
[6] Mohd Ibrahim M Y, Ramadhansyah P J, Mohd Rosli H, Wan Ibrahim M H 2016 *ARPN Journal of Engineering and Applied Sciences* **11(20)**11832-11835
[7] Ye Q, Zhang Z, Kong D and Chen R 2007 *Constr Build Mater* **21** 539-545

[8] Mohd Ibrahim M Y, Ramadhansyah P J, Mohd Rosli H and Wan Ibrahim M H 2015 *Jurnal Teknologi* **76(14)** 99-103
[9] British Standards Institution. BS1881-113: Testing concrete: Method for making and curing no-fines test cubes. British Standards. London: BSi 2011
[10] British Standards Institution.. BS EN 12390-3: Testing hardened concrete: Compressive strength of test specimens. British Standards. London: BSi 2002
[11] British Standards Institution. BS EN 12390-6: Testing hardened concrete: Tensile splitting strength of test specimens. British Standards. London: BSi 2009
[12] British Standards Institution. BS EN 12390-5: Testing hardened concrete: Flexural strength of test specimens. British Standards. London: BSi 2009
[13] Ramadhansyah P J, Badorul Hisham A B, Megat Azmi M J and Mohd Haziman W I *Cent Eur J Eng* **1(1)** 103-112
[14] Siddharth T, Jayeshkumar P. and Chetna M V 2015 *Int. J. Adv. Engg. Res.* **4(2)** 296-299
[15] Akeke G A, Ephraim M E, Akobo I Z S and Ukpata J O 2013 *Int. J. Eng.* **3(3)** 57-62
[16] Wang L, Zheng D, Zhang S, Cui H and Li D 2016 *Nanomaterials* **6(12)** 241
[17] Ramadhansyah P J, Mohd A A M N, Zainal A A and Zakaria M A 2013 *Adv Mat Res* **620** 87-93