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Performance of Kaolin Clay on the Concrete Pavement

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Abstract. This paper investigates the performance of concrete pavement containing kaolin clay with their engineering properties and to determine the optimum kaolin clay content. The concrete used throughout the study was designed as grade 30 MPa strength with constant water to cement ratio of 0.49. The compressive strength, flexural strength and water absorption test was conducted in this research. The concrete mix designed with kaolin clay as cement replacement comprises at 0%, 5%, 10% and 15% by the total weight of cement. The results indicate that the strength of pavement concrete decreases as the percentage of kaolin clay increases. It also shows that the water absorption increases with the percentage of cement replacement. However, 5% kaolin clay is found to be the optimum level to replace cement in a pavement concrete.

1. Introduction

Concrete pavement has been utilized for many areas such as highways, airports, parking lots, industrial facilities, and various types of infrastructure [1]. Concrete pavements if designed properly and built from durable materials according to the specifications, can provide long duration of service with little or almost no maintenance at all [2]. Nowadays, the introduction of new materials as concrete ingredient is getting popular due to strict environmental legislations [3]. Research on different materials as substitution and replacement for cement such as kaolin clay, palm oil ash (POFA) and rice husk ash have been used in construction [4,5,6]. In Europe, a code of practice has been enforced for the use of waste materials in cement and dolomitic lime manufacture [5]. This is to solve waste problem and to improve the sustainability of operation by reducing the use of natural raw materials. With continuous production worldwide, the current utilization of waste by-product is believed to rise with the realization of environmental benefits that contributes to the protection and sustainability of future construction [6]. One possible source is kaolin clay, presented as fine particles, is beneficial to some properties of PCC such as compressive strength and segregation.

2. Material and methods

2.1. Cement
Ordinary type I Portland cement (Blue Lion Cement) (OPC) was used as the major binder in the production of moderately strong concrete. The OPC was chemically analyzed using an X-ray fluorescence (XRF) apparatus, in accordance with the procedures in BS EN 197-1 [9]. According to Dewi et al. [10] the chemical composition of OPC was 70% calcium oxide, 17.8% silicon dioxide, 3.9% aluminium oxide, 3.2% iron oxide, 1.5% magnesium oxide and 3.6% sulfur trioxide.

2.2. Kaolin
The only pozzolanic material that used in this research is the kaolin clay. The pozzolanic shall conform to the prescribed chemical composition requirements and physical requirements as stated in the ASTM C618 [11]. Kaolin is neither the by-product of an industrial process nor is it entirely natural.

2.3. Aggregate
Local natural sand from granite was used as fine aggregate in concrete mixtures. In addition, crushed granite with a single size of 20 mm was used as coarse aggregate. The coarse and fine aggregates both had a specific gravity of 2.66 and water absorption of 0.48 and 0.86%, respectively.

2.4. Compressive strength test
Compressive strength is commonly considered the most important property of concrete. In this study, the compressive strength test of all the concrete mixes was performed on 100×100×100 mm cubes. The specimens were compressed by a compression machine with a maximum capacity of 3000kN and a loading rate of 150kN/min. The reported compressive strength was the average of the three samples. The test was conducted according to the British standard test method BS EN 12390-3 [12].

2.5. Flexural strength test
The flexural strength test of specimens was carried out using the prims flexural test. Three pavement concrete prims specimens of 100×100×500 mm were prepared. These specimens were tested at 7, 14, and 28 days and then reported. The mean readings of maximum stress applied to the concrete prims by 3-point load test using flexural-testing machine were recorded, and the data were used to calculate the flexural strength of the pavement concrete prims containing the prepared blended binders. The flexural strength test was carried out in accordance with BS EN 12390-5 [13].

3. Results and Discussion

3.1. Compressive strength
Figure 1 demonstrates the compressive strength of Portland cement pastes when affected by the replacement percentage. The concrete exhibits an upward projection in compressive strength as the concretes ages. The ordinary Portland cement concrete continued to gain strength over time with value for all percentage of cement replacement. With an increase in age, the degree of hydration increase as will the compressive strength. For instance, the control samples recorded is 37.51 N/mm^2 at age of 7 days. At the age of 28 days, the kaolin replaced concrete continues to gain strength over time. The highest strength recorded is 46.05 N/mm^2 for control mix at 28 days which is still higher than any of the kaolin replaced concrete mix. With all kaolin replacement, there is a reduction in cement amount for the concrete paste. This is in turn reducing the released amount of C-H gel from the hydration process. The C-H gel does react with the admixtures and rapidly removes calcium hydroxide from the system and accelerate the ordinary Portland cement hydration [14]. It can be said that all different blended concrete pavement decrease in compressive strength when they are compared to the control sample's compressive strength. Therefore, an optimum replacement recorded is for 5% replacement.

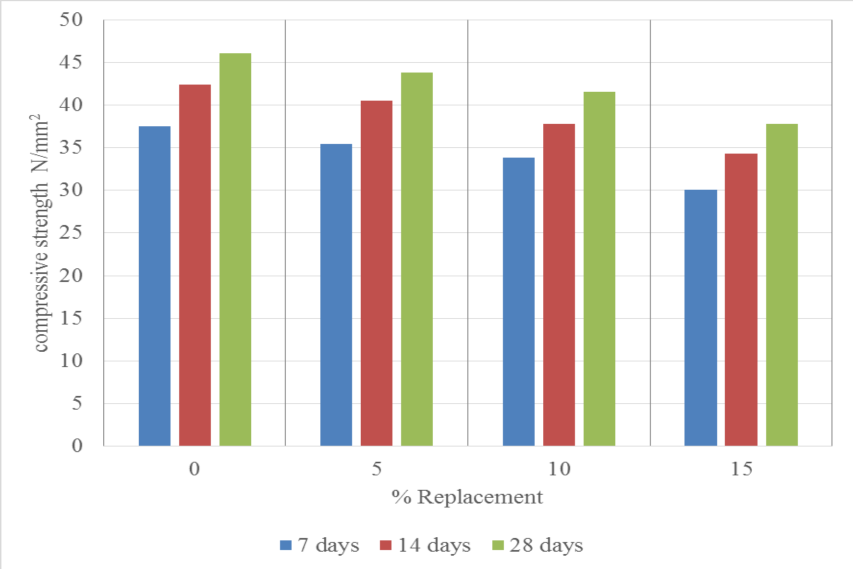

Figure 1. Strength of pavement concrete at different kaolin replacement

3.2. Flexural Strength

Figure 2 shows the flexural strength with different percentage of replacement. The concrete exhibits an upward trend in flexural strength with an increase in age and curing. At 28 days, the control samples recorded with flexural strength of 3.82 MPa. While for 5% of cement replacement, the concrete recorded flexural strength of 3.80 MPa. Figure 2 shows that with all cement replacement, it exhibit lower flexural strength than the control mixes. The flexural strength decreased slightly to 3.75 MPa with 10% replacement. However, at 15% replacement, the flexural strength drops up to 3.73 MPa. At 5% replacement, the flexural strength of concrete was achieving 3.80 MPa. The flexural strength is found to decrease by the addition of admixtures due to the decrease in bond strength as they form a rigid structure comparatively. This phenomenon is decrease in flexural strength of concrete.

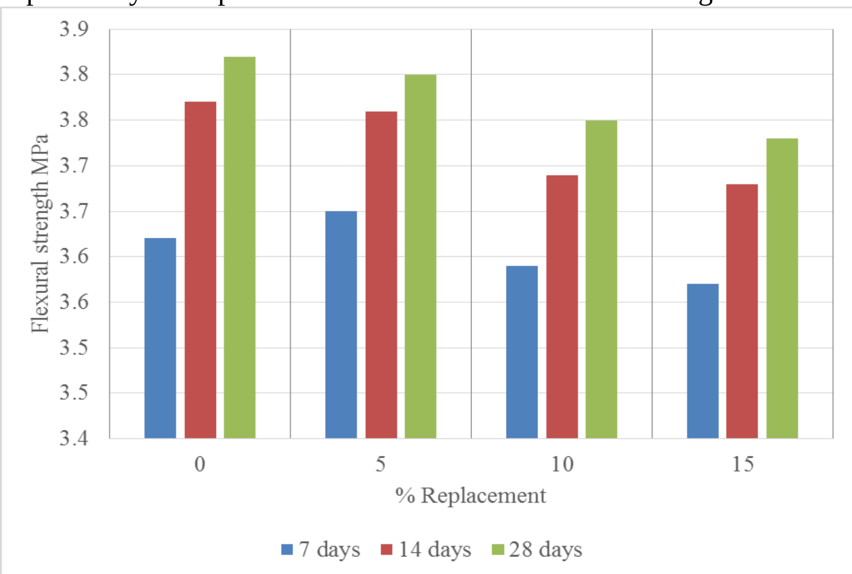

Figure 2. Flexural strength of pavement concrete at different kaolin replacement

3.3. Water Absorption

Water absorption is measured by measuring the increase in mass as a percentage of dry mass. Water absorption has significant effects to the durability of pavement concrete. Table 1 shows the water absorption at 28 days with different percentage of replacement. It can be observe that the water absorption is directly proportional to percentage of cement replacement. The water absorption of the control sample is 1.14% and continues to increase for each replacement with the exception for the 15% cement replacement. However, at 15% replacement of kaolin clay, the water absorption was about

1.51%. The increase in water absorption indicates higher amount of void in the concrete. Kaolin clay suspends in the paste. This will increase the spacing between fine aggregate. When high amount of kaolin, any more than 3%, air void began to level out.

Table 1. Water absorption with different % kaolin replacement

% replacement	Water absorption		
	WW	DW	% different
0	2.301	2.275	1.14
5	2.279	2.248	1.37
10	2.320	2.281	1.71
15	2.287	2.253	1.51

3.4. Relationship between Strength and Water Absorption

Figure 3 shows the relationship between compressive strength and water absorption. It can be seen that the higher the water absorption, the lower the strength of the concrete. The results also show that the two lines directly related. There is an observable decreases in compressive strength from 46.05 N/mm^2 to 37.83 N/mm^2 as the water absorption increases from 1.14% to 1.51%. The drop in compressive strength can be due to the amount of kaolin clay in the concrete mix. As the amount of kaolin clay increase, the more water is absorbed by the kaolin. It increase the water absorption but due to the lack of cement to bind the aggregate together. Therefore, compressive strength decreases because of the increase in water absorption. The structure of kaolin is affected by the adsorption of heavy metals. The displacement of H+ ions and the adsorption of the cations of Pb, Zn or Cd could create swelling, internal stress in the molecule, flocculation, a decrease in shear strength and an increase in hydraulic conductivity and compressibility [15]. All those changes listed above indicate the creation of empty spaces in the clay structure.

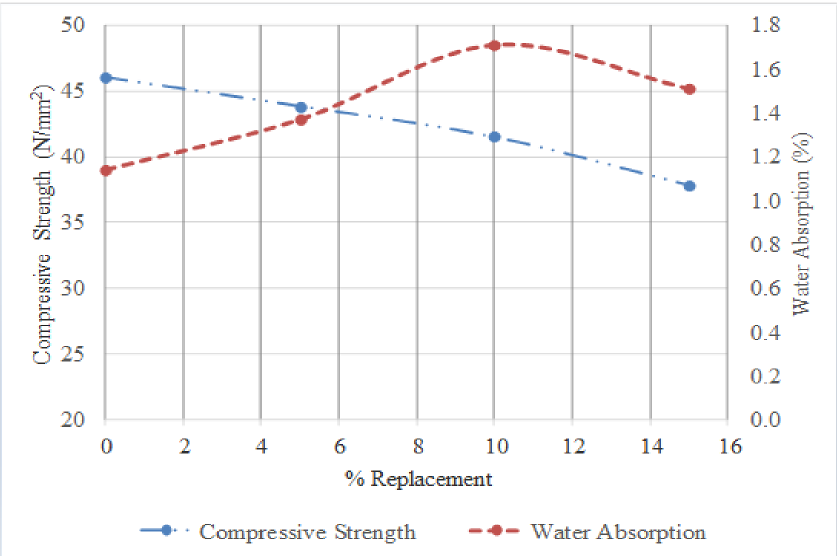

Figure 3. Relationship between strength vs. water absorption

4. Conclusions
Admixture of kaolin can decrease the compressive strength of concrete. However, among kaolin clay replacement, 5% has the highest compressive strength compared to the other two values of replacements. Furthermore, kaolin clay also decreases the flexural strength of concrete. But, 5% of the binder replacement has the highest flexural strength when compared to the other two values of replacements. In addition, water absorption has significant effects to the durability of pavement concrete. It can be seen that the water absorption continuously increase with increment kaolin clay, except at 15% cement replacement.

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References
[1] Asi M, Qasrawi H Y and Shalabi F I 2007 *Can. J. Civil Eng.* **34** 902–911.
[2] Shafiq N, Nuruddin M F, Khan S U and Ayub T 2015 *Const. Build. Mater*. **81** 313-323.
[3] Ilić B, Radonjanin V, Malešev M, Zdujić M and Mitrović A 2016 *Appl. Clay Sci*. **123** 173-181.
[4] Lotfy A, Karahan O, Ozbay E, Hossain K M A and Lachemi M 2015 *Const. Build. Mater*. **83** 102-107.
[5] Khalid N H A, Hussin M W, Mirza J, Ariffin N F, Ismail M A, Lee H.-S, Mohamed A and Jaya R P 2016 *Const. Build. Mater*. **102** 950–960.
[6] Jayanti D S, Mirza J, Jaya R P, Abu Bakar B H, Hassan N A and Hainin M R 2016 *P. I. Civil. Eng-Mar. Eng*. **169** 76-85.
[7] Liu F, Meng L-y, Ning G-F and Li-Juan Li 2015 *Const. Build. Mater*. **95** 207-217.
[8] Anastasiou E K, Liapis A and Papayianni I 2015 *Resour. Conserv. Recy*. **101** 1-8.
[9] BS EN 197-1 2011 *Cement. Composition, specifications and conformity criteria for common cements*. BSI, London, UK.
[10] Dewi S J, Ramadhansyah P J, Norhidayah A H, Md. Maniruzzaman A A, Hainin M R and Mohd Haziman W I 2014 *Appl. Mech. Mater*. **554** 203-207.
[11] ASTM C618 2015 *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*. ASTM International, West Conshohocken, PA.
[12] BS EN 12390-3 2009 *Testing hardened concrete. Compressive strength of test specimens*. BSI, London, UK.
[13] BS EN 12390-5 2009 *Testing hardened concrete. Flexural strength of test specimens*. BSI, London, UK.
[14] Abu Bakar B H, Ramadhansyah P J and Megat Azmi M J 2011 *Mag. Concrete Res*. **63** 313-320.
[15] Chen C, Habert G, Bouzidi Y, Jullien A and Ventura A 2010 *Resour. Conserv. Recycl*. **54** 1231–1240.