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CHEMICAL RESISTANCE OF METAKAOLIN BLENDED CEMENT CONCRETE

A.G. IBRAHIM[1], D. DAHIRU[2], S. GAMBO[3], J. USMAN[4], S.A. SHIKA[5] AND I.M. KHALIL[6]

[1,2,3,4,5,6]Department of Building, Ahmadu Bello University, Zaria
Corresponding author; getsomsc12012@gmail.com
Tel: +2348060907165

ABSTRACT

The use of pozzolanic materials as partial replacement of cement in concrete is on increase in order to promote sustainability in construction industry. This paper evaluated the effect of MK as cement replacement on the resistance of concrete to chemicals. Two different samples of concrete were produced. One with 10% (binary) MK replacing cement and another without MK as control. These samples were exposed to 3.5%NaCl, 1%$MgSO_4$ and 2%$MgSO_4$ solutions up to 90 days. After exposure, the strength and abrasion resistance of the samples were determined. Results showed that concrete sample with MK has improved compressive strength by about 9.8% and 12.3%, higher abrasion resistance by about 0.04% than the control at 28 and 90 days respectively. MK has positive effects on the mechanical and durability properties of the concrete. Therefore, MK can be used in the production of concrete exposed to sea water and sulphate environment.

KEY WORDS: *Chemical resistance, Metakaolin, Magnesium sulphate, Sodium chloride*

INTRODUCTION

Currently, the use of pozzolanas in concrete has been on increase in order to curb the CO_2 emission and energy consumption associated with cement production (Aiswarya, Prince and Dilip, 2013, Biljana *et al*, 2011). Nowadays, pozzolans are widely used as supplementary cementing materials in Portland cements and may replace part of the clinker in order to enhance the performance of the hydrated cement (Indrawati and Manaf, 2008). Pozzolanic materials are silicious or silicious and aluminous materials which in themselves posses little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at an ordinary temperature, to form compounds possessing cementitious properties (Shetty, 2009).

Some of the pozzolans are natural and others are by-products (artificial) and both contain silica in amorphous form and that will react with calcium hydroxide (C-H) to form more cementitious calcium silicate hydrate (C-S-H) which contribute to the concrete strength (Habeeb and Mahmud, 2009, Najigivi *et al*., 2010). When incorporated in binary blends, pozzolanic materials are known to react with calcium hydroxide (CH), which is a product of cement hydration, to produce additional reaction products, such as calcium silicate hydrate(C-S-H) which improves strength and porosity (Shiathas *et al*, 2004). Such composite or blended cements are employed for their economic, ecological and technological benefits (Suryawanshi *et al*, 2015).

However, one of the materials that satisfies the requirements of sustainable development and, when added in appropriate proportions, improves the properties of cement, mortars and concrete, is metakaolin (MK), a processed pozzolana (Biljana *et al*, 2011). MK is a high quality pozzolanic material which improves the durability of concrete and mortars; it removes chemically reactive calcium hydroxide from the hardened cement paste. MK reduces the porosity, densifies the thickness of interfacial zone; this improves the adhesion between the hardened cement paste and particles of sand or aggregates (Murthy *et al.,* 2012).

The kaolinitic clay from which MK is obtained is abundant in Nigerias (Kovo and Edoga 2005, Lori *et al*, 2007, Badmus and Olatinsu, 2009). It is produced by heat-treating (650-900°C) kaolin, a natural, finely divided, alumino-siliceous mineral, alters its structure, producing a highly reactive supplementary cementitious material (Kurtis, 2011).

Recently, a lot of research works have been carried out on the viability of using MK as supplementary cementitious materials in the production of concrete. Such efforts include: Justice (2005) who observed that MK increases compressive strength, elastic modulus and resistance to chemical attack of concrete, as compared to conventional concrete. Ghorpade and Rao, (2011), Justice *et al*, (2005) observed that chloride ion permeability value decreased considerably with increase in MK content in concrete, thus indicating improved durability with increasing MK content. According to Kurtins (2007 and 2011), MK increases compressive strength, impermeability and durability of concrete due to its high surface area and reactivity. Momtazi *et al* (2007) noted that MK can decrease permeability, increase compressive strength and concrete durability.

However, only a few research studies have examined the incorporation of MK for the production of blended concrete in Nigeria on the use of the abundant kaolinitic deposits in the country, resulting in a body of knowledge which is much less complete compared to the literature available for rice husk ash binary blend system. Baba and Usman (2011) investigated the heating parameters for converting Kankara kaolin clay to MK with a view to ascertaining the possibility of using Nigerian Kaolin Clay as concrete material. It was found out that the optimum thermal condition for the calcination of kankara kaolin was 650ºC in 90 minutes, and it can be used for partial replacement of cement. They further concluded that the optimum percentage replacement of cement with kankara MK is 10% which agreed with Suryawanshi *et al*, (2015) study. But such a research has not exposed the sample to any aggressive medium. Therefore, this research sought to evaluate the chemical resistance of concrete made from kankara MK using the optimum percentage replacement.

MATERIALS AND METHODS

Materials

The materials used in this study includes: Ordinary Portland Cement (OPC) Dangote brand that satisfies the requirements of BS EN 197-1:2011 was used throughout the experiment, fine aggregates, coarse aggregates, MK and water that satisfy the requirement of BS EN 12620:203, ASTM 618 05 and BS EN 1008:2005 respectively. The OPC used was manufactured by Dangote cement company Plc. The coarse aggregate used was crushed gravel while the fine aggregate was fine river sand.

Method

Chemical composition analysis: the test was carried out in order to ensure that the MK meets the requirement of ASTM 618-05. The result of the test is shown Table 1.

Workability: At fresh stage the concrete sample was tested for workability using compacting factor in accordance with BS EN 12350-2:2009 and the result is shown in Figure 1.

Compressive strength: At hardened stage, the concrete specimens were tested for compressive strength at 28 and 90 days in accordance with BS EN 12390-3 (2009). The result is shown in Figure 2.

Abrasion resistance: samples were tested for abrasion resistance and the result is shown in Figure 4.

RESULTS AND DISCUSSION

The results of the different tests on the concrete constituents and concrete samples described above are as follows:

Table 1. Chemical Composition of Cement and Metakaolin

Oxide	Content %	
	Cement	Metakaolin
Al_2O_3	4.9	40.0
SiO_2	20.1	54.9
TiO_2	0.2	0.096
K_2O	0.4	-
CaO	65	0.802
Na_2O	0.2	-
MgO	3.1	0.027
MnO	0.02	-
Fe_2O_3	2.5	0.082
Loss on Ignition	8.8	13

Source: Experiment (2016)

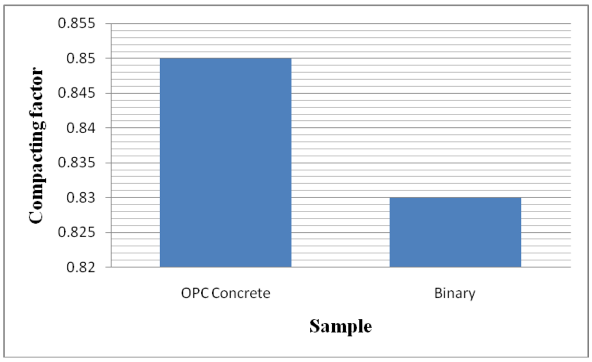

Figure 1. Compacting Factor Test

Figure 1 above shows the workability assessment of the two concrete samples (OPC concrete & binary). The OPC concrete has a compacting factor of 0.85 while the binary has 0.83. This implies that the binary concrete absorbed water more than the OPC concrete which may be due to the high surface area of MK. The decrease in the workability is in agreement with what Justice (2005) and Momtazi *et al* (2007) observed.

The results of the compressive strength test of OPC concrete (as control) and binary concrete

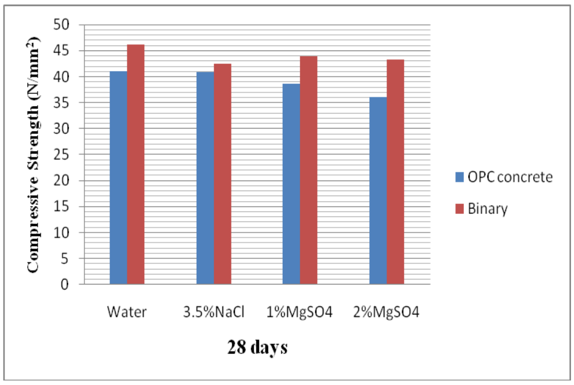

Figure 2. Compressive strength at 28 day

are shown in the Figure 2. It can be observed that at the 28 day, the average compressive strength of the OPC is 41.1N/mm^2 while that of binary is 46.1 N/mm^2. This shows that the binary concrete is higher in strength than the OPC by about 15%. When these samples were exposed to the aggressive media (3.5%NaCl, 1%$MgSO_4$ & 2%$MgSO_4$), the OPC concrete strength dropped by 0.5%, 3% and 10% respectively than the control sample, while the binary has strength of 6%, 9.8% and 8.3% respectively higher than the control despite exposure to the aggressive media. The severity of the media is highest in 2%$MgSO_4$ and lowest in 3.5%NaCl. The improvement in the strength of the binary could be due to MK ability to decrease permeability and increase in compressive strength as asserted by Kurtins (2011), and Sabu Rijuldas & Aiswarya (2016). Moreover, the strength increase could be due to the micro filling effect of MK on calcium hydroxide which accounts for up to 25% of the hydrated Portland cement (Concrete Countertop Institute2007). The calcium hydroxide does not contribute to the concrete's strength or durability. MK combined with the calcium hydroxide to produce additional cementing compounds, (calcium silicate hydrate), that enhances the microstructure and hence the strength of the concrete Rashad (2015), Aiswarya, Prince, & Dilip (2013) Momtazi *et al* (2007), Murthy *et al.*(2012). Less calcium hydroxide and more cementing compounds means stronger concrete.

The results of the compressive strength test of OPC concrete (as control) and binary concrete are shown in the Figure 3. It can be observed

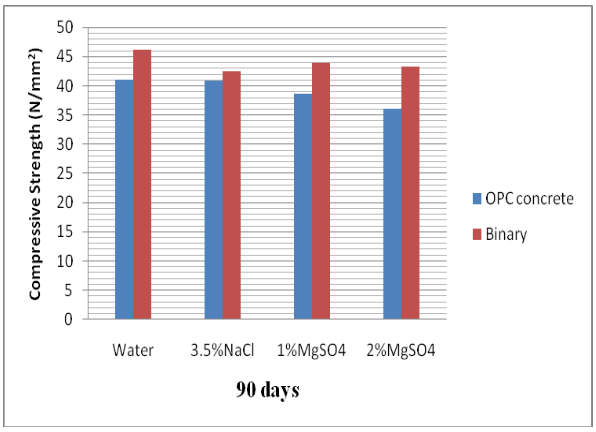

Figure 3. Compressive strength at 90 day

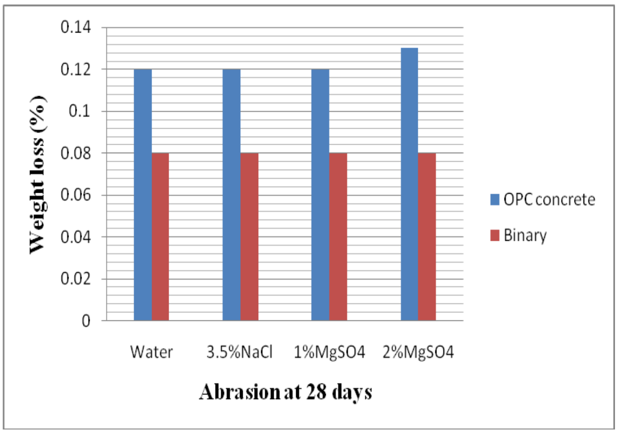

Figure 4. Abrasion resistance at 28 day

that at the 90 day, the average compressive strength of the OPC is 41.4N/mm^2 while that of binary is 47 N/mm^2. This shows that the binary concrete is higher in strength than the OPC by about 18%. When the samples were exposed to the aggressive media (3.5%NaCl, 1%$MgSO_4$ & 2%$MgSO_4$), the OPC concrete strength dropped by 23%, 7% and 17.7% respectively than the control sample, while the binary has strength of 6.8%, 12.3% and 8% respectively higher than the control despite exposure to the aggressive media. At the 90 day, the severity of the media is highest in 3.5%NaCl and lowest in 1%$MgSO_4$ for the control sample while for binary, it is highest in 3.5%NaCl and lowest in 2%$MgSO_4$. The improvement in the strength of the binary and resistance to the chemicals could be due to MK ability to decrease permeability and increase compressive strength as asserted by Kurtins (2011), and Sabu, Rijuldas & Aiswarya (2016). Moreover, the strength increase could be due to the micro filling effect of MK on calcium hydroxide which accounts for up to 25% of the hydrated Portland cement (Concrete Countertop Institute2007). The calcium hydroxide does not contribute to the concrete's strength or durability. MK combined with the calcium hydroxide to produce additional cementing compounds, (calcium silicate hydrate), that enhances the microstructure and hence the strength of the concrete Rashad (2015), Aiswarya, Prince, & Dilip (2013) Momtazi *et al* (2007), Murthy *et al*(2012). Less calcium hydroxide and more cementing compounds means stronger concrete.

Figure 4 shows the abrasion resistance (in terms of % loss in weight) of OPC and binary concretes at 28 day. The resistance of the concrete samples (OPC & binary) is 0.12% and 0.08% respectively. The binary has more resistance to abrasion (by 0.04%) than the control. When these samples were exposed to the aggressive media (3.5%NaCl, 1%$MgSO_4$ & 2%$MgSO_4$), the resistance of the control is the same except in 2%$MgSO_4$, where it is 0.13%. That of binary remains the same thing throughout but higher (0.05%) than the control in 2%$MgSO_4$. MK combined with the calcium hydroxide to produce additional cementing compounds, (calcium silicate hydrate), that enhances the microstructure and hence the strength of the concrete Rashad (2015), Aiswarya, Prince, & Dilip (2013) Momtazi *et al* (2007), Murthy *et al.*(2012). Less calcium hydroxide and more cementing compounds means more resistance to abrasion.

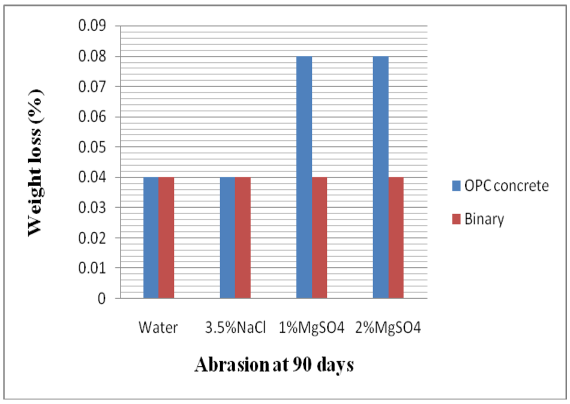

Figure 5. Abrasion resistance at 28 day

Figure 5 shows the abrasion resistance (in terms of % loss in weight) of OPC and binary concretes at 90 day. The resistance of the concrete samples (OPC & binary) is 0.04%.When these samples were exposed to the aggressive media (3.5%NaCl, 1%$MgSO_4$ & 2%$MgSO_4$), the resistance of the control is the same except in $MgSO_4$ where it is 0.08% (lower by 0.04%). That of binary remains the same thing throughout the media. MK combined with the calcium hydroxide to produce additional cementing compounds, (calcium silicate hydrate), that enhances the microstructure and hence the strength of the concrete Rashad (2015), Aiswarya, Prince, & Dilip (2013) Momtazi *et al* (2007), Murthy *et al* (2012). Less calcium hydroxide and more cementing compounds means more resistance to abrasion.

CONCLUSION

Based on the results of the research, the following conclusions were reached:

i. Binary concrete with MK has reduced workability by about 2.4% compared to the OPC.
ii. The inclusion of MK resulted in faster early age strength development of binary concrete than plain OPC concrete.
iii. The binary concrete has improved compressive strength and durability when exposed to chemical attacks (NaCl & $MgSO_4$).
iv. The severity of the aggressive media is more pronounced in 3.5%NaCl.
v. MK from Kankara kaolin can be used for concrete production in sea water and sulphate environment.

REFERENCES

Aiswarya S, Prince A. G. and Dilip C., (2013), A Review on Use of Metakaolin In Concrete, *IRACST – Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498,*

Baba S.U. and Usman B. (2011), Thermal Treatment of Kankara Kaolin Clay to Produce Metakaolin as Partial Replacement of Cement in Concrete Production, *A Final Year Project, Submitted to the Department of Building Faculty of Environmental Design Ahmadu Bello University,* Zaria

Badmus B.S. and Olatinsu O.B., (2009), Geophysical evaluation and chemical analysis of kaolin clay deposit of Lakiri village, southwestern Nigeria, *International Journal of Physical Sciences* Vol. 4 (10) pp. 592-606, ISSN 1992 – 1950 *www.academicjournals.org/.../pdf/pdf2009/.../ Badmus%20and20Olatinsu Accessed 23/09/2011 at 12:14 PM.*

Biljana I. *et al.* (2011), Metakaolin: Kaolin clay Cement production, *http://www.doiserbia.nb.rs/img/doi/0367-598X/2009/0367-598X0902107M.pdf, accessed 23/09/2011 at 10:12a*

The Concrete Countertop Institute, www.ConcreteCountertopInstitute.com, *accessed 23/09/2011 by 10:06am*

Gambhir M.L. (2006), Concrete Technology, Tota McGraw-Hill Publishing Company Limited, NewDelhi, India.

Ghorpade V.G. and Rao H.S. (2011), Chloride Ion Permeability Studies of Metakaolin Base High Performance Concrete, i*nternational journal of engineering science and technology (IJEST) ISSN:0975- 5462, PP. 1617-1623.,* htt://www.ijest.info/docs/TJEST 11-03-0288.pdf, accessed 23/09/2011 by 09:49am.

Habeeb G.A. And Mahmud H.B. (2009), Pozzolans for Sustainable Concrete, *International Conference for Technical Postgraduate (TECHPOS), Towards Advancement of Engineering Research-Global Challenges, Kuala Lumpur, Malaysia.*

Justice M.J. (2005), Evaluation of metakaolin for use as supplementary Cementitious materials, *An M.sc. thesis presented to the academic faculty, Georgia Institute of technology, www.etd.gtech.edu/thesis 30/06/2011, 8:58PM*

Justice M.J. *et al* (2005), Comparison of two Metakaolins and Silica Fume as Supplementary Cementitious materials, *Proc. Seventh international symposium on utilization of high- strength/high performance* *concrete held in Washington D.C., June 20-24, 2005. www.innovateatthiele.com/pdf/Ga_Tech-Kaorock_Reports-cmbin, accessed 23/09/2011.*

Kovo A.S. and Edoga M.O. (2005), Production and Characterisation of Zeolite fromAhako Clay in Kogi State, Nigeria, *Leonardo Electronic Journal of Practices and Technologies,*P.31-40,ISSN 1583-1078.*www.lejpt.academicdirect.org/A07/31_40 pdf accessed 23/09/2011.*

Kurtins K. (2007), Metakaolin, Lauren McCormick, CEE 8813-Material Science of Concrete*, www.people.ce.gatech.edu/~kk92/mkgrad, accessed 23/09/2011.*

Kurtins K.E. (2011), Benefits of Metakaolin in HPC, *HPC Bridge Views, ISSUE www.hpcbridgeviews.com/i67/Article3.asp, accessed 23/09/2011.*

Lori J.A. *et al* (2007), Characterisation and Optimisation of Deferration of Kankara Clay, *ARPN Journal of Engineering and Applied Sciences, Asian Research Publishing Network (ARPN),* Vol. 2, No. 5, October 2007, pp. 60-74. ISSN1819-66, www.arpnjournals.org/jeas/research_papers/rp_2007/jeas_1007_68.pdf, accessed 23/09/2011.

Momtazi A.S. *et al* (2007), The effect of Iran's metakaolin in enhancing the concrete Compressive strength, *Department of civil engineering, University of guilan*, *www.claisse.info/special%/20papers/sadrmomtazi_full_text.pdf*, *accessed 23/09/2011.*

Murthy N.K. *et al.,* (2012), The Influence of Metakaolin on the Modulus of Elasticity of Concrete, IOSR Journal of Engineering (IOSRJEN), www.iosrjen.org,

NajigiviA.*et al* (2010), Contribution of Rice Husk Ash to the Properties of Motar and Concrete, *Journal of American Science, USA, http://.www.Americascience.Org, accessed 23*/09/2011.

Shetty M.S. (2009), Concrete Technology: Theory and Practice, S. Chand &Company Ltd,Ran Nagar, New Delhi, India

Shiathas C. et al (2004), A Comparative Study of the Properties and Durability of Binary and Ternary Cementitious Systems, University of Surrey, UK.

Suryawanshi*et al*, (2015), Experimental Study on Compressive Strength of Concrete by Using Metakaolin, International Research Journal of Engineering and Technology (IRJET), www.irjet.net accessed 14/11/2015.

The Concrete Countertop Institute, www.ConcreteCountertopInstitute.com, *accessed 23/09/2011*