SUITABILITY OF ALKALINE ACTIVATED METAKAOLIN AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

ADEJOH BENJAMIN OCHOLA1, IBRAHIM SHUAIBU2, MUSTAPHA ABDULHAKEEM3
Department of Civil Engineering, Kaduna Polytechnic

ABSTRACT
This study is aimed at investigating the compressive strength of concrete using metakaolin as a replacement for cement in concrete using three grades of concrete; grade 20, 25 and 30 respectively, the concrete cube cast was; control (0%) 5%, 10%, 15% and 20% respectively. the cube was cast, cured and tested at 7days and 28days. The results of this study have shown a significant increase in compressive strength of concrete utilizing metakaolin than normal concrete, it could be recommended that metakaolin of 5%, 10% & 15% replacement can be used for the different grades of concrete, while 20% replacement of metakaolin can be used in road kerbs, concrete blocks, non-bearing concrete walls, Light Weight Concrete, precast units (partition walls, concrete blocks for Architectural applications and some cases of slabs on soil, culverts, sidewalks, drive ways), foundation pads for machinery, etc.

Keywords: *Cementious material, Compressive strength, Metakaolin, Pozzolana, filler,*

Introduction
Concrete is one of the most common materials used in the construction industry. In the past few years, many research and modification has been done to produce concrete which has the desired characteristics. There is always a search for concrete with higher strength and durability. In this matter, blended cement concrete has been introduced to suit the current requirements. Cementitious materials known as pozzolans are use as cement constituents, in addition to Portland cement. Originally the term pozzolan was associated with naturally formed volcanic ashes and calcined earths will react with lime at ambient

temperatures in the presence of water. Recently, the term has been extended to cover all siliceous/aluminous materials which in finely divided form and in the presence of water, will react with calcium hydroxide to form compounds that possess cementitious properties. The current area of research in the concrete is introducing clay (metakaolin) in the concrete (Sabir B.B et.al, 2014).

Clays have been and continue to be one of the most important industrial minerials. Clays and clay minerals are widely utilized in our society. They are important in geology, agriculture, construction, engineering, process industries and environmental applications. Traditional applications of clay including ceramics, paper, paint, plastics, drilling fluids, chemical carriers, liquid barriers, and catalysis. Research and development activities by researchers in higher education and industry are continually resulting new and innovative products (Patil S.N. et.al, 2014)

Metakaolin is one of the innovative clay products developed in recent years. It is produced by controlled thermal treatment of kaolin. Metakaolin can be used as a concrete constituent, replacing part of the cement content since it has pozzolanic properties. The use of metakaolin as a partial replacement material in mortar and concrete has been studied widely in recent years. Despite of the recent studies, there are still many unknowns with the use of metakaolin. Study is needed to determine the contribution of metakaolin in the performance of hardened concrete. There are great concerns on the strength and durability of metakaolin – concrete when used as construction industries. If it is proven that the concrete is durable and strong, this lead to the use of metakaolin to replace part of the cement (Patil S.N. et.al, 2014).

The introduction of pozzolans as cement replacement materials inrecent years seems to be successful. The use of pozzolan has proven to be an effective solution in enhancing the properties of concrete in terms of strength and durability. The current pozzolans in use are such as fly ash, silica fume and slag. Development and investigation of other sources of pozzolan such as kaolin will be able to provide more alternatives for the engineer to select the most suitable cement replacement material for different environments.

Unlike other pozzolans, Metakaolin is not a by-product which means its engineering values should promise some advantages compared to other cement replacement materials. In this case, studies are needed to study the performance of Metakaolin – concrete will be compared to the cost of production of

Metakaolin to determine whether Metakaolin is worthy to be developed as a new cement replacement material.

In addition, the use of Metakaolin is not common in the Nigerian Construction sector. This study will be able to enhance the understanding on the suitability of Metakaolin as cement replacement material.

Material and Method

Metakaolin

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in manufacture of porcelain. The particle size of Metakaolin is smaller than cement particles, but not as fine as silica fume.

Materials

The clay Samples under investigation was subjected to activation process. The method of activation was compounded from various methods described by Bradley & Grim (1951), Grim & Kulbicki (1961) and Joshi et al (1961).

For activation, 50kg of local clay (Metakaolin) powder (12xx, BS 410) was digested with 250cm of concentrated sulphuric acid for 3hour in a mixer apparatus. After cooling, the solid washed with distilled water several times until the washings were neutral (pH 7.0).

The washing water was decanted and the solids dried at 100^{o}C for 1hour and then heated between 350 - 500^{o}C in an aching furnace for about 2hour. The solids obtained after heat activation were sieved to obtain particle size passing through mesh size 250um used for subsequent work.

Compressive strength test

Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc.

For cube test, casting was done using 150mm X 150mm X 150mm concrete mould. The concrete is poured in the mould and tempered 35 times in three (3)

layers properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen is made even and smooth. These specimens are tested by compression testing machine (digital display) after 7 days and 28 days curing. Load are applied gradually until the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Results and Discussion

Table 1: Compressive Strength of Control, 5%, 10%, 15% and 20% (Grade 20)

Age (Days)	Crushing strength (N/mm2)				
	Control	**5% Repl.**	**10% Repl.**	**15% Repl.**	**20% Repl.**
7	**12.3**	**17.2**	**18.1**	**19.8**	**19.0**
28	**20.4**	**21.2**	**22.8**	**24.3**	**23.1**

Table 2: Compressive Strength of Control, 5%, 10%, 15% and 20% (Grade 25)

Age (Days)	Crushing strength (N/mm2)				
	Control	**5% Repl.**	**10% Repl.**	**15% Repl.**	**20% Repl.**
7	**16.6**	**22.5**	**23.7**	**25.5**	**24.0**
28	**25.6**	**26.1**	**26.7**	**28.2**	**27.0**

Table 3: Compressive Strength of Control, 5%, 10%, 15% and 20% (Grade 30)

Age (Days)	Crushing strength (N/mm2)				
	Control	**5% Repl.**	**10% Repl.**	**15% Repl.**	**20% Repl.**
7	**21.0**	**24.0**	**24.9**	**26.1**	**25.2**
28	**30.6**	**31.2**	**32.0**	**37.9**	**32.3**

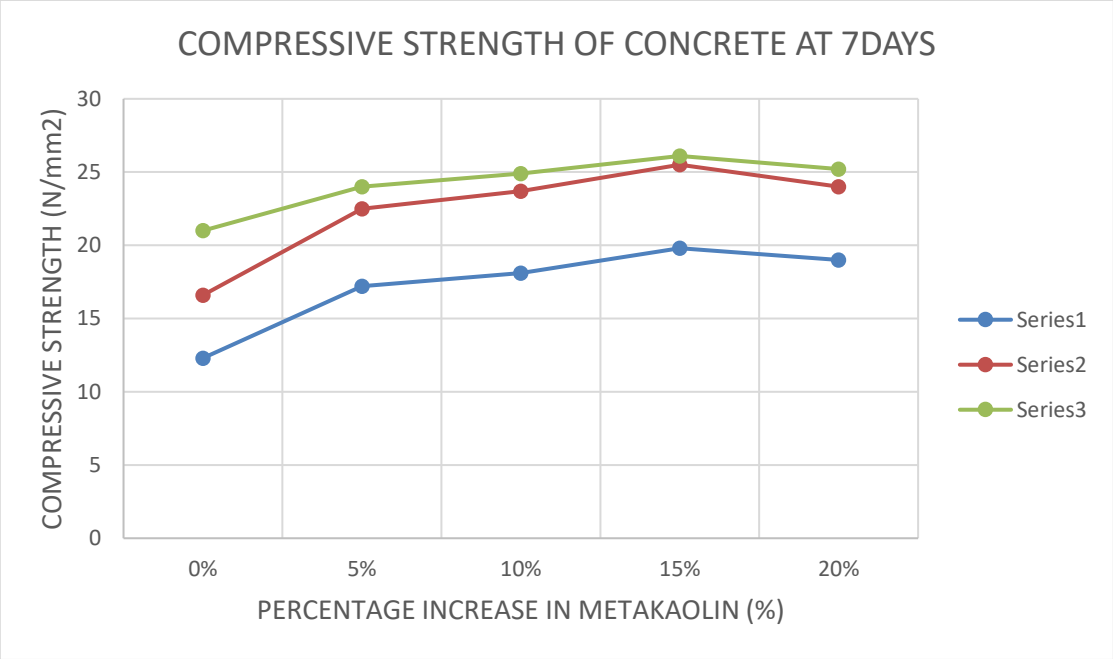

Fig. 1: A graph of compressive strength (N/mm2) against % increase in metakaolin at 7days

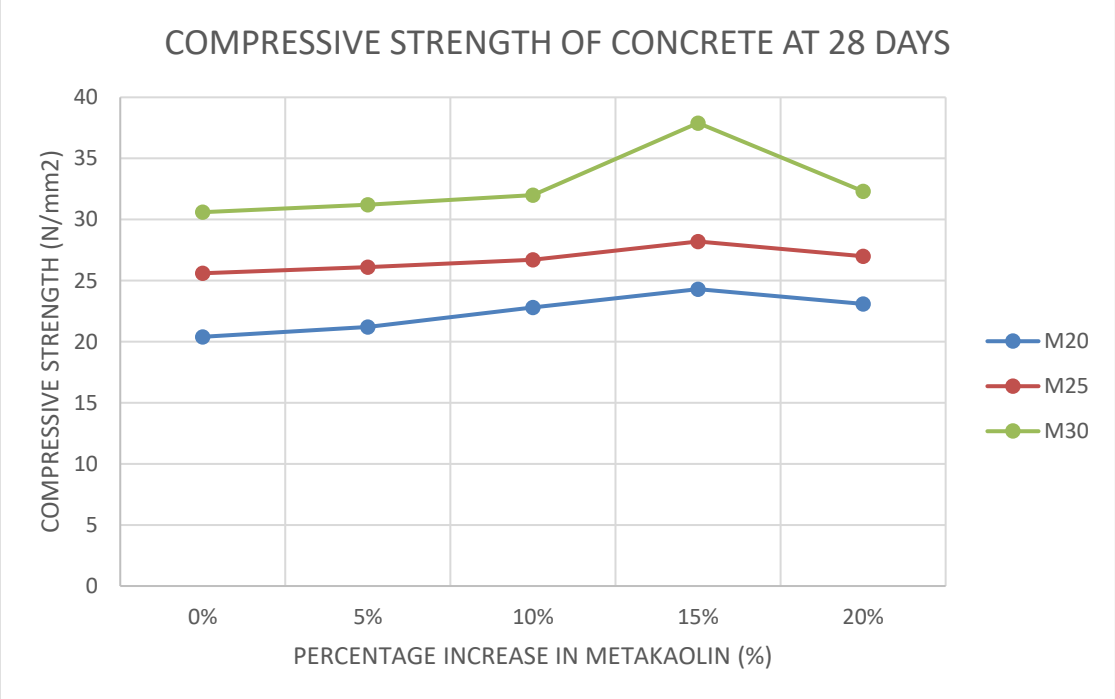

Fig. 2: A graph of compressive strength (N/mm2) against % increase in metakaolin at 28 days

Discussion of Result

The result obtained from the entire test carried out on the sample of concrete is as follows:

The compressive strength grade 20, 25 and 30 for 0%, 5%, 10%, 15%, and 20% were obtained as follows: Concrete grade 20 7 days = 12.3N/mm2 , 17.2N/mm2, 18.1N/mm2 ,19.8N/mm2,and 19.0N/mm2 28 days = 20.4N/mm2, 21.2N/mm2, 22.8N/mm2 , 24.3N/mm2, and 23.1N/mm2. Concrete grade 25 7 days = 16.64N/mm2, 22.54N/mm2, 23.74N/mm2, 25.54N/mm2, and 24.04N/mm2, 28 days = 25.6N/mm2, 26.1N/mm2, 26.7N/mm2, 28.2N/mm2, and 27.0 N/mm2. Concrete grade 30 7 days = 21.0N/mm2, 24.0N/mm2, 24.9N/mm2, 26.1N/mm2 and 25.2N/mm2, 28 days = 30.6 N/mm2, 31.2 N/mm2, 32.0N/mm2, 37.9N/mm2, and 32.3N/mm2.

Therefore, the result above shows that increase in percentage of replacement up to 15% increases the strength of concrete for both grade 20, 25 and 30 and increases in strength with increase in curing days.

The results of this trend may be due to a increase in workability with increase metakaolin up to 15%. Test to assess the workability of fresh concrete indicates that incorporation of metakaolin in concrete leads to increase in slump value, which depends on the metakaolin content. This increase in slump was due to the retention of some quantity of mixing water by metakaolin particles.

From the compressive strength result, most of the cubes crushed were able to attain 65% strength in 7days curing and maximum strength in 28days curing. Also all the grades of concrete were able to gain maximum strength at 15% addition of metakaolin and begin to lose its strength at 20% addition of metakaolin.

Conclusion

From the result obtained in this study, it can be concluded that metakaolin can be used as a potential material for replacing cement. There is an increase in strength with increase in curing age, an increase in strength with an increase in percentage replacement up to 15% of the metakaolin.

Recommendations

The results of this study have shown a significant increase in compressive strength of concrete utilizing metakaolin than normal concrete, it could be

recommended that metakaolin of 5%, 10% & 15% replacement can be used for the different grades of concrete, while 20% replacement of metakaolin can be used in road kerbs, concrete blocks, non-bearing concrete walls, Light Weight Concrete, precast units (partition walls, concrete blocks for Architectural applications and some cases of slabs on soil, culverts, sidewalks, drive ways), foundation pads for machinery, etc.

References

A.V.S.Sai. Kumar et.al, (2014). A Study on Strength of Concrete with Partial Replacement of Cement with Quarry Dust and Metakaolin. ISSN: 2319-8753, PP 10467- 10473

B.B.Sabir et.al, (2001). Metakaolin and calcined clays as pozzolanas for concrete: a review. Cement & concrete composites 23(2001) 441-454. Incorporation of Metakaolin in Concrete: A Review http://www.iaeme.com/IJCIET/index.asp 2editor@iaeme.com

Chandrakant u. mehetre , pradnya p. urade , shriram h. mahure & k. ravi4, (2014). comparative study of properties of self compacting concrete with metakaolin and cement kiln dust as mineral admixtures, impact: International Journal of Research in Engineering & Technology (IMPACT: IJRET), Vol. 2, Issue 4, Apr 2014, 37-52

Dr. D. V. Prasada Rao and S. Venkata Maruthi, (2016). "Effect of Nano-Silica on Concrete Containing Metakaolin". *International Journal of Civil Engineering and Technology (IJCIET)*, 7(1), 2016, pp.104–112.

Erhan Guneyisi, Mehmet Gesoglu, Kasim Mermerdas, (2007). "Improving strength, drying shrinkage and pore structure of concrete using Metakaolin", Materials and structures, 2007, Vol 12, pp: 10-26.

G. Batis, P. Pantazopoulou, S. Tsivilis, E. Badogiannis, (2005). "The effect of metakaolin on the corrosion behaviour of cement mortar", Cement and concrete composites, 2005, Vol 27, pp: 125-130.

J. M. Justice, L. H. Kennison, B. J. Mohr, S. L. Beckwith, (2005). "Comparison of Two Metakaolin and a silica fume used as a supplementary Cementitous materials", High Performance concrete, 2005, pp: 20- 24.

J.M. Khatib et.al, (2012). High Volume Metakaolin as Cement Replacement in Mortar. World Journal of Chemistry, ISSN 1817- 3128, © IDOSI Publications, DOI: 10.5829/idosi.wjc.2012.7.1.251

Kannan, V. and Ganesan, K. (2014) "Chloride and chemical resistance of self-compacting concrete containing rice husk ash and Metakaolin" ELASIVER Construction and Building Materials 51, pp 225–234.

P. Dinakar (2011) "High reactive metakaolin for high strength and high performance concrete", The Indian Concrete Journal, 2011, pp: 28-34.

Patil, B.B. and Kumbhar, P.D. (2012) "Strength and Durability Properties of High Performance Concrete incorporating High Reactivity Metakaolin" IJMER Vol.2, Issue.3, ISSN: 2249-6645. Pp 1099-1104.

Sabir, B.B., Wild, S. and Bai, J. (2014) "Metakaolin and calcined clays as pozzolanas for concrete : A review, Cement & concrete composites" Elsevier CCC-23(2001) pp 441-454.

Sai, A.V.S. and Rao, K.B. (2014) "A Study on Strength of Concrete with Partial Replacement of Cement with Quarry Dust and Metakaolin" ISSN: 2319-8753, Vol. 3, pp 10467-10473.

Terrence Ramlochan, Michael Thomas, Karen A. Gruber (2000) "The effect of metakaolin on alkali-silica reaction in concrete". Cement and concrete research, 2000, Vol 30, pp: 339-344

Varma, D. and Rao, G.V.R. (2014) "Influence of Metakaolin in High Strength Concrete of M70 Grade for Various Temperatures and Acidic Medium" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 3 Ver. VII, pp 32-37.

Vivek Sood , Ashok Kumar , S.K. Agarwa (2014) Comparative Hydration Behavior of Metakaolin-Microfine System, Journal of Engineering Computers & Applied Sciences(JECAS), Volume 3, No.4, April 2014, pp:60-65