International Journal of Chemical Engineering Research.
ISSN 0975-6442 Volume 10, Number 2 (2018), pp. 85-94

http://www.ripublication.com

Effect of Dealuminated Kaolin Waste on Slump and Compressive Strength for Ordinary Portland Cement Concrete

H.Moselhy*

**The Higher Institute of Engineering, Chemical Engineering Department, Shorouk City, Cairo, Egypt.*
Corresponding author: H.Moselhy

Abstract

Dealuminated kaolin waste obtained from Aluminium sulphate company in Egypt causes environmental problems.

The possibility of using it as cementious material in concrete was studied. Additions of 0% dealuminated kaolin waste up to 15 % were investigated. Properties such as slump and compressive strength were measured.

Keywords: Dealuminated kaolin waste, slump test, compressive strength, concrete

1. INTRODUCTION

Kaolin is a clay mineral. It is uncreative in its natural form. So it is heated to a temperature greater than 500^{o}C to increase the surface area for reaction. The metakaolin formed is mixed with sulphuric acid to produce alum which is used in clarification of water. The dealuminated kaolin (Alum waste) is one of the environmental problems worldwide today.

Egypt is producing alum for water purification from domestic kaolin (35% Al_2O_3) as bauxite, the conventional raw material for alum production with Al_2O_3 is not available. [1, 2, 3, 4,5,]

Rheological properties of a fresh cement paste play an important role in determining the workability of concrete. The water requirement for flow, hydration behaviour, and properties of the hardened state largely depends upon the degree of dispersion of cement in water. Properties such as fineness, particle size distribution, and mixing intensity are important in determining the rheological properties of cement paste.[6]

In this work, Dealuminated kaolin waste was characterized in physical and in chemical points of view. Effect of additions of 0% dealuminated kaolin waste up to

15 % of dealuminated kaolin waste on slump and also compressive strength were made.

2. EXPERIMENTAL TECHNIQUES

2.1 Materials

2.1.1 Sand

Natural sand composed of siliceous materials was used as fine aggregate in this study. The sand was graded. It passes from sieve 850µm and is retained on 600 µm.

2.1.2 Water

Tap water was used for mixing concrete for all specimens.

2.1.3 Ordinary Portland cement (OPC)

OPC produced by el- Suez cement company with grade 42.5 is used. Testing of cement was carried out as the Egyptian standard specialization ESS4756-1/2009, where the retained on science # 170 was less than 10%. Table 1 shows the chemical composition of OPC.

Table 1: Shows the chemical composition of ordinary Portland cement

Compound	SiO_2	Al_2O_3	Fe_2O_3	Cao	MgO	SO_3	Na_2O	K_2O	Cl^-	LOI
OPC	22.11	5.12	3.42	62.8	1.42	2.01	0.2	0.13	0.02	2.52

2.1.4 Dealuminated kaolin waste

Dealuminated kaolin waste supplied from (Shaba Al- Masria) is dried at 110 ^oC for 24 h. Then was analysed as shown in table 2.

Table 2: Chemical analysis of dealuminated kaolin waste

Main Constituents	**(wt%)**
SiO_2	71.86
TiO_2	2.95
Al_2O_3	7.48
$Fe_2O_3^{tot}$.	0.51
MgO	0.08
CaO	0.31
Na_2O	0.11
K_2O	0.08
P_2O_5	0.05

Main Constituents	(wt%)
SO_3	5.28
Cl	0.02
L.O.I	10.98
Cr_2O_3	0.02
Y_2O_3	0.01
SrO	0.02
Nb_2O_5	0.02
CeO_2	0.02
ZrO_2	0.2

Also dealuminated kaolin is subjected to XRD. The results illustrated in Fig. 1 reveal that its main crystalline phases are quartz and anatase (TiO_2). The presence of alumina and sulfur oxide in the XRF analysis (table 2) suggests the presence of aluminum sulfate presumably in amorphous state as no characteristic lines showed up in the XRD pattern. Stoichiometric calculations based on the XRF results have been performed. They show that most of the alumina in the waste is present as part of the unreacted metakolin and only a minor portion (about 10%) is present as aluminum sulfate. Assuming that metakaolin has the chemical symbol $Al_2O_3.2SiO_2$, this will result in having about 8% of the available silica present in combined metakaolin form. The percent free silica should then be about 64%.

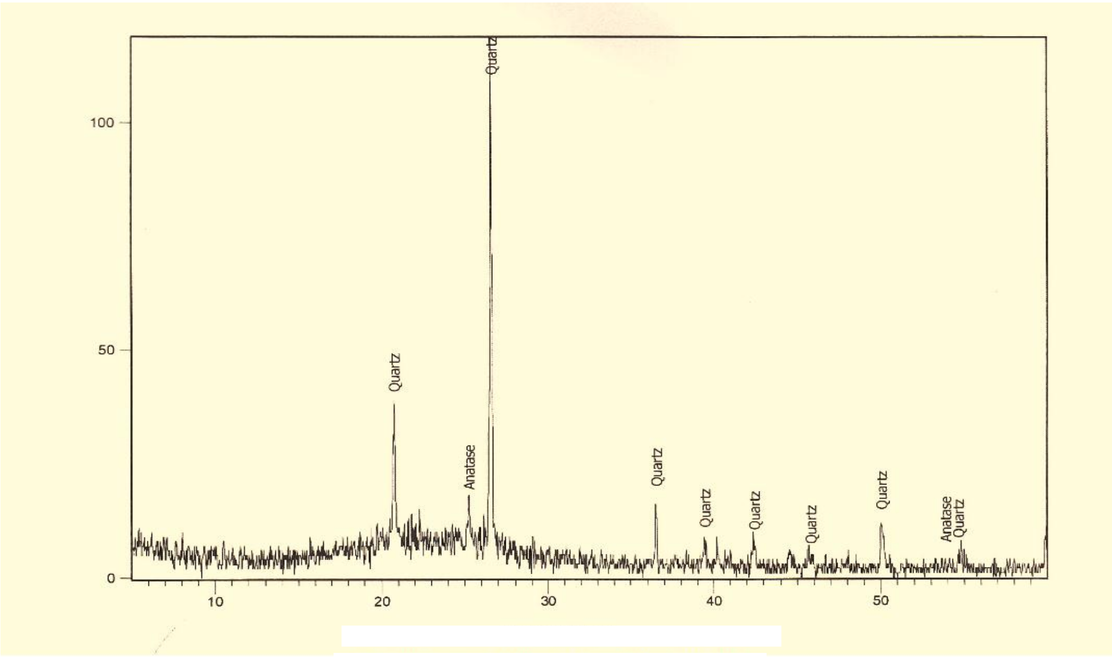

Fig.1: X-ray diffraction of dealuminated kaolin waste

2.2 Mixing and curing

The percentage of cement to sand ratio was kept constant at 1:2.75 by weight in all mixes.

Dealuminated kaolin was used as a replacement or as an addition of 0% up to 15% of cement by weight.

Mixing was done in a standard drum type mixer; fine aggregate, cement and alum waste were mixed in dry state until the mixture becomes homogenous, then water was added to dry mixture and was mixed for minutes.

The test specimens were immersed in water in curing tanks after 24 hours for 28 days.

3. RESULTS AND DISCUSSIONS

3.1 Effect of dealuminated kaolin waste on compressive strength and slump test

The compressive strength and slump test with varying percentage replacement of dealuminated kaolin waste in M-25 grade of concrete was investigated. Table (3) represents the mix proportion.$\mathbf{M_{25}}$ grade of concrete was adopted where (Cement/Water) fixed at 0.5 and(Sand/Coarse aggregate)fixed at 0.5 Wt. %.Testing of Ordinary Portland Cement Concrete was carried out according to the **BS 1881 [7,8].**

3.1.1 Compressive strength

Cubic moulds are made of steel or cast iron with an internal tolerance of ±0.025 mm. When the mould is properly assembled, its dimensions should be correct to ±0.2 mm.

3.1.2 Procedure

1. Weigh the quantities of cement, fine aggregate, coarse aggregate and water for one batch of concrete, to an accuracy of 0.1% of the total weight of batch.
2. Mix the concrete by hand or preferably in laboratory batch mixer avoiding loss of any material or water. The period of mixing should not be less than two minutes after adding all materials in drum, in case of machine mixing.
3. Mix first in case of hand mixing cement and fine aggregate until a uniformly blended mixture is obtained. Add coarse aggregate to the earlier mix and mix all materials and until all materials are uniformly spread throughout the batch. Add water and mix the entire batch until the all materials are uniformly and be homogeneous and attain the required consistency.
4. Apply a thin coat of oil to the base plate and interior faces of the moulds, prevent adhesion of concrete.
5. Fill the moulds with fresh concrete in layers approximately 5 cm deep, place the concrete and move it around top edge of the mould, allowing the concrete to slide in a symmetrical manner without any segregation.
6. Place the mould on vibration table in case of compaction by vibration and vibrate

each layer until the specified condition is reached.

7. Distribute the over entire surface in case of hand compaction by using standard tamping rod.
8. Ensure uniform filling for the three moulds. The specimens are then cured for twenty eight days in water so as to attain the desired compressive strength.
9. Remove the cubes from water, the area of loading face of cubes (A) determined in (mm^2), and then placed between plates of universal testing machine.
10. Apply the load to the specimen faces that are in contact with the machine until failure and the result noted (F).
11. Calculate the compressive strength of cement mortar as an average between three specimens in each run from the relation:

$$\sigma_{comp} = \frac{F}{A},\ MPa$$

Table 3: Mix proportion of each batch

Mix designation	% Waste	OPC, kg	Alum waste, kg	Sand, kg	Coarse aggregate, kg	Water, kg
M_0	0.00	4.6	0.00	8.2	16.4	2.3
M_1	5	4.37	0.23	8.2	16.4	2.3
M_2	10	4.14	0.46	8.2	16.4	2.3
M_3	15	3.91	0.69	8.2	16.4	2.3

3.1.3 Slump cone test for fresh concrete(9) **.**

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the placability of the concrete. The pattern of slump is shown in Fig.(2). It indicates the characteristic of concrete in addition to the slump value. If the concrete slumps evenly it is called true slump. If one half of the cone slides down, it is called shear slump. In case of a shear slump, the slump value is measured as the difference in height between the height of the mould and the average value of the subsidence.

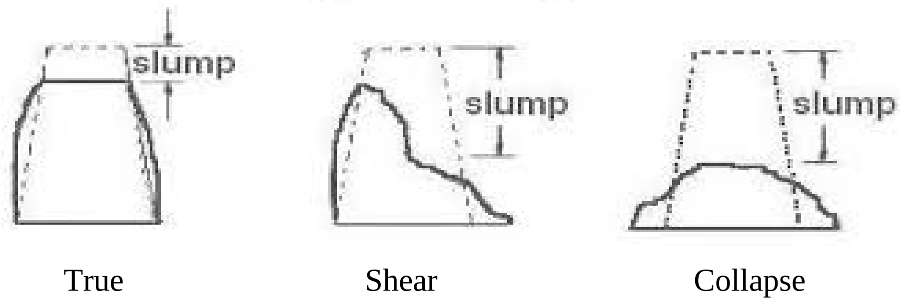

Fig. 2: Slump Types of Concrete

3.1.4 Procedure

1. Place the mould on a flat, moist, nonabsorbent (rigid) surface. It shall be held firmly in place during filling by the operator standing on the two foot pieces. Immediately fill the mold in three layers, each approximately one third the volume of the mould.
2. Distribute the strokes uniformly over the cross section of each layer.
3. In filling and rodding the top layer, heap the concrete above the mold before rodding start. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all time.
4. After the top layer has been rodded, strike off the surface of the concrete by means of screeding and rolling motion of the tamper.
5. Remove the mold immediately from the concrete by raising it carefully in the vertical direction. Raise the mold a distance of 300 mm in 5 ± 2 sec by a steady upward lift with no lateral or torsional motion.
6. Immediately measure the slump by determining the vertical difference between top of the mould and the center of the top surface of the specimen. Complete the entire test from the start of the filling through removal of the mold without interruption and complete it within 2½ min.
7. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make a new test on another portion of the sample. If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of concrete from the mass of specimen, the concrete lacks necessary plasticity and cohesiveness for the slump test to be applicable.
8. After completion of the test, the sample may be used for casting of the specimens for the future testing.

4. ENVIRONMENTAL IMPACT AND CARBON DIOXIDE EMISSIONS

Reduction of the cement quantities in concrete making is the main target of this study which will directly reflect on decreasing the carbon dioxide (green house) gas emission rate at cement manufacturing sites. Portland cement is considered as the major contributor element of green house gas emission asit has been reported that cement industry is responsible for 5% of global anthropogenic carbon dioxide emission as stated by Humphreys and Mahasenan**(10)**.

5. CONCLUSION

Slump test

The experimental results indicate that slump steadily with increasing percentage of dealuminated kaolin waste as cement replacement due to the porous character of the waste. This causes the concrete to absorb more water for the same workability. The results obtained are presented in Fig. (4).

Compressive Strength

It was found from the experimental results that the compressive strength increases for specimens upon increasing the percentage of Alum waste as replacement for cement when compared with the conventional concrete up to about 7% replacement after which it starts decreasing. The test results obtained are presented in Fig. (4).

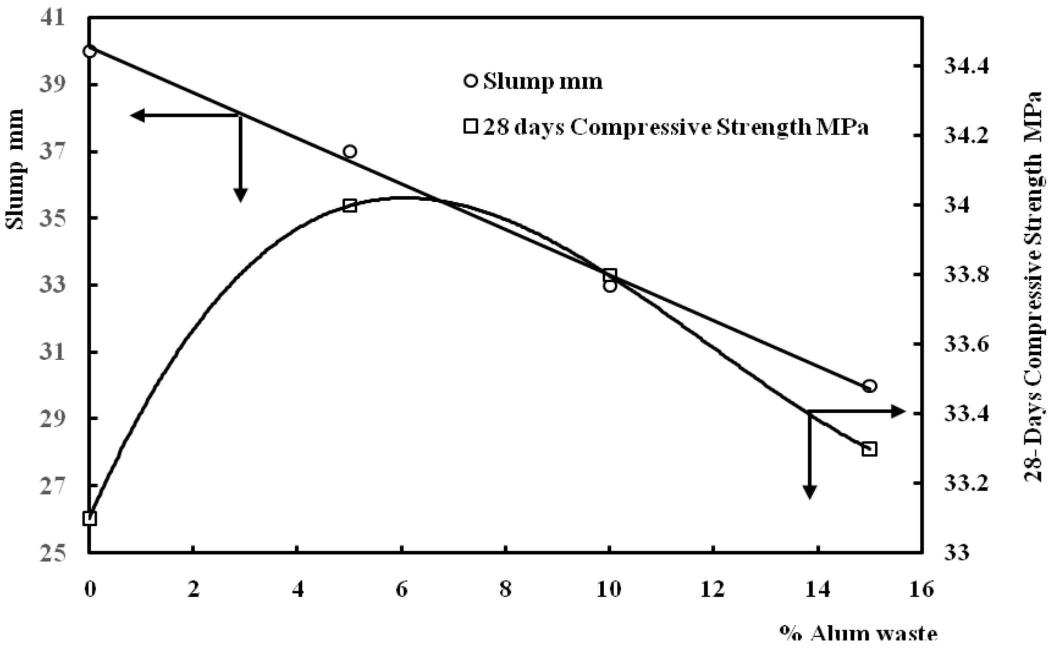

Fig. 4: Effect of substituting cement by as-received alum waste in concrete on 28 days compressive strength

It is observed that 5% replacement of cement with Alum waste increased the compressive strength of concrete by 2.8%. The other percentage of Alum waste such as 10 and 15 percentages also showed considerable increase in strength characteristics of the concrete when compared with the conventional concrete.

6. ECONOMIC ANALYSIS AND ENVIRONMENTAL IMPACT.

For decreasing the cost of construction materials and raising environmental concerns, considerable efforts are being taken worldwide to utilize waste and byproduct materials to improve the performance of construction materials. Conventional building materials are beyond the reach of a majority of the world population since their poor affordability.

Pozzolanic materials when used in mortar and concrete works improve later strength and durability of concrete and decrease materials costs significantly **[11]**.

Reduction in cost for 1m^3 concrete with 15 % Alum waste as cement replacement material can be calculated with using table (4.11) as follows including the most recent prices of cement (March 2018)[12]:

$$\text{Percent saving} = \frac{420-357}{420+63+252+0} = 8.6\%$$

Table 4. Economic analysis

Material	Cost (LE/ton)	Amount (ton/m^3 concrete)		Cost (LE/m^3)	
		M_0	M_3	M_0	M_3
Cement	1200	0.35	0.2975	420	357
Fine aggregate	100	0.63	0.63	63	63
Coarse aggregate	200	1.26	1.26	252	252
Alum waste	0.00	0.00	0.0525	0.00	0.00

CONCLUSION

Trials taken place on concrete to replace cement by alum waste as-received. The results showed that:

- 5% replacement of cement with Alum waste increased the compressive strength of concrete by 2.8%. The other percentage of Alum waste such as 10 and 15 percentages also showed considerable increase in strength characteristics of the concrete when compared with the conventional concrete.

- The slump has decreased for the specimens with varying percentage of Alum waste as replacement for cement when compared with the conventional concrete
- 8.6% reduction in cost for $1m^3$ concrete with 15 % Alum waste as cement replacement material.
- 12.6 %, (from 0.340 to 0.297 MT) reduction in green house gas emission (carbon dioxide) was estimated per cubic meter concrete batch manufacture.

REFERENCES

(1) Benjamin, o. Aderemi, Lawrence edomwonyi-otu and sam S. Adefila "A new approach to metakaolin dealumination" Australian Journal of Basic and Applied Sciences, 3(3): 2243-2245, 2009

(2) Salwa A. Ahmed, Mohamed A. Tantawy, Elham M. Abdallah, Mostafa I. Qassim "Characterization and application of kaolinite clay as solid phase extractor for removal of copper ions from environmental water samples" International Journal of Advanced Research (2015), Volume 3, Issue 3, p.p 1-3

(3) Ajayi, A.O., Atta, A.Y., Aderemi, B.O. and Adefila, S.S. "Novel method of metakaolin dealumination -preliminary investigation" Journal of Applied Sciences Research, 6(10): 1539-1541, 2010

(4) Mohammed, J., Faizu, A. L., Usman, D. H. and Murtala, A. M "Production of alum from alkaleri kaolin, Nigeria" International Journal of Advanced Scientific and Technical Research Issue 3 volume 2, March-April 2013,p.p 308-309

(5) ABDELAZIZ, G.E,. ABDELALIM, A.M.K, GHORAB, H.Y. and. ELSAYED, M.S" Characterization of OPC matrix containing dealuminated kaolin" concrete reasearch,vol1(4) December 2010,p.p

6) Rudolf, H. and Marsalova, J." Study of metakaolin influence on rheological properties of cement mortars" Annual Transactions of the Nordic Rheology society, vol 17, 2009

7) ASTM C 109 (2002) “Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. Cube Specimens)”, Annual Book of ASTM Standards, ASTM International, Vol. 04.01, West Conshohocken, PA, 2003.

8) BS 1881, British Standards for Testing concrete.

9) ASTM C143/C143M(2015) “Standard Test Method for slump of Hydraulic Cement concrete.

10) Humphreys K. and Mahasenan M.: 2002, ‘Toward a sustainable cement industry’, substudy 8, climate change, World Business Council for Sustainable Development.

11) Hu J., Wang K., (2005) Effects of Aggregate on Flow Properties of Mortar, Proceedings of the 2005 Mid-Continent Transportation Research Symposium, Ames, Iowa State University.

12) Bendary H.I.(2018)"Characterization of alum waste and its use in construction industry" PhD thesis, Cairo university.