International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 3 Issue 5, August 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

The Effect of Dosage and Modulus of Activator on the Strength of Alkali Activated Slag and Fly Ash Based on Geopolymer Mortar

Nyein Nyein Thant[1], Zin Mar Soe[2]

[1]Associate Professor, [2]Lecturer

[1,2]Department of Civil Engineering, Technological University, Mandalay, Myanmar

How to cite this paper: Nyein Nyein Thant | Zin Mar Soe "The Effect of Dosage and Modulus of Activator on the Strength of Alkali Activated Slag and Fly Ash Based on Geopolymer Mortar" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-5, August 2019, pp.2220-2224, **https://doi.org/10.31142/ijtsrd27997**

IJTSRD27997

ABSTRACT

In this study, the effect of dosage and modulus of activator on the strength of alkali activated slag and fly ash based geopolymer mortar is studied. Fly ash from Tingyi is used. Blast furnace slag from No (1) Iron and Steel Industry, Pyin Oo Lwin is used. NaOH and Na_2SiO_3 are used as alkaline activator. Firstly, the physical properties of slag, fly ash and sand are tested. Alkali activated slag mortar is mixed with various proportion of activator. And the tests are made eight times with different activator dosage for slag mortar. Then the test is made once again without activator. Water - (slag + cement) ratio of 0.35 is used for this test. Fly ash based geopolymer mortar is mixed various proportion of activator. And the tests are made eight times with different activator dosage for fly ash based geopolymer mortar. Then the test is made once again without activator. Water - fly ash ratio of 0.33 is used for this test. For both testing, samples are cured at 85°C for 24 hours and left at room temperature until the day of testing. The samples are tested for 3, 7, 14 and 28 days compressive strength. Then the compressive strength test results obtained from various dosages of activator and without activator are compared.

KEYWORDS: *geopolymer mortar, Alkali activated slag mortar, compressive strength*

I. INTRODUCTION

In various civil engineering projects, cement is used as construction materials. In construction works, the usage of cement is replaced with fly ash and slag by reducing suitable amount of cement.

Geopolymer cements is used to produce structural strength concrete without the considerable CO_2 emission that characterizes Portland cement manufacture. Geopolymer are formed when alumino-silicates, such as fly ashes and slag dissolve in alkali solution.

Mortar is used as a binding material of stone brick and concrete and a coarsening material to wall in the form of plaster to provide a smooth hard and decorative surface in construction. In general, cement mortar is made by cement and sand. Geopolymer mortar is made up of fly ash or slag, sand and alkali activator. In recent year, fly ash is available from power industry and slag is available from the Iron and Steel Industry in our country. Fly ash and slag are replaced for part of Portland cement and used in the construction of a number of dams, bridges and other large projects. If fly ash and slag are widely used in constructions, many advantages can achieve.

II. Testing of Materials And Alkaline-Activator

In this study, fly ash, slag, cement and fine aggregates are tested to know their properties.

A. Testing of Fly Ash

Fly ash is one of the residues generated in the combustion of coal. A fly ash from Tigyit Coal Fired Thermal Power Station is used in this study. The specific gravity and chemical composition of fly ash used in this study are shown in Table 1 and Table 2.

Table 1 Test for Specific Gravity of Fly Ash

Data Sheet for Specific Gravity of Fly Ash		
Test Name	Specific Gravity	
Sample Name	I	II
Bottle No.	3277	4432
Wt of Bottle W_1	37.2	36.4
Wt of Bottle + fly ash W_2	47.5	46.6
Wt of Bottle + fly ash + kerosene W_3	122.1	119.8
Wt of Bottle + kerosene W_4	116.2	114
Wt of fly ash $(W_2 - W_1)$	10.3	10.2
Wt of kerosene $(W_3 - W_2)$	74.6	73.2
Wt of fly ash $(W_4 - W_1) - (W_3 - W_2)$	4.4	4.4
G.S (Fly Ash) = $\frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$	2.34	2.31
Average	2.32	

Table 2 Normal Range of Chemical Composition for Fly Ash

Chemical Component	Contained (%)
Silica (SiO_2)	45.62
Alumina (AL_2O_3)	10.84
Ferric Oxide (Fe_2O_3)	4.42
Calcium Oxide (CaO)	30.25
Magnesium Oxide (MgO)	1.43
Sulphur Trioxide (SO_3)	2.47
Loss on Ignition (LOI)	4.35

The summary of test results of fly ash is shown in Table 3. This table includes many tests. These tests are fineness test, consistency test, specific gravity test, setting time test.

Table 3 Summary of Test Results of Fly Ash

Sample Name	Fly Ash	
Fineness (cm^2/g)	2488	
Consistency (%)	29%	
Specific Gravity	2.32	
Setting Time(hr:min)	Initial Set	0:10
Without activator	Final Set	2:00
Setting Time(hr:min)	Initial Set	0:15
With NaOH	Final Set	2:10
Setting Time(hr:min)	Initial Set	0:15
With $NaOH+Na_2SiO_3$	Final Set	2:00
Setting Time(hr:min)	Initial Set	0:20
With Na_2SiO_3	Final Set	2:30

B. Testing of Slag

In this research, blast furnace slag from No (1) Iron and Steel Industry, Pyin Oo Lwin is used. Chemical compositions of blast furnace slag are used in this study as shown in Table 4.

Table 4 Normal Range of Chemical Composition for Slag

Chemical Constituent	Composition in percent (%)
Silica (SiO_2)	23.42
Alumina (Al_2O_3)	5.74
Ferric Oxide (Fe_2O_3)	7.65
Calcium Oxide (CaO)	25.76
Manganese Oxide (MnO)	19.2
Sulphur (S)	0.28
Carbon (C)	1.06
Mangnese (Mn)	0.928

The summary of test results of slag is shown in Table 5. This table includes many tests. These tests are fineness test, consistency test, specific gravity test, setting time test.

Table 5 Summary of Test Results of Slag

Sample Name	Slag	
Fineness (cm^2/g)	1285	
Consistency (%)	17.50%	
Specific Gravity	3.87	
Setting Time(hr:min)	Initial Set	0:15
Without activator	Final Set	0:50
Setting Time(hr:min)	Initial Set	0:25
With NaOH	Final Set	0:45
Setting Time(hr:min)	Initial Set	0:15
With $NaOH+Na_2SiO_3$	Final Set	0:25
Setting Time(hr:min)	Initial Set	0:05
With Na_2SiO_3	Final Set	0:20

C. Chemical Compositions of Cement

Cement is a binding material and forms a paste when contacts with water, which holds the fine aggregate together to form solid mass. In this study, slag mortar combined with AAA cement. Slag cannot be used only because it does not fuse and bind with sand. The chemical compositions of AAA cement are shown in Table 6.

Table 6 Chemical Compositions of AAA Cement

Chemical Constituent	Composition in percent (%)
Silica (SiO_2)	19.42
Alumina (Al_2O_3)	4.4
Ferric Oxide (Fe_2O_3)	3.47
Calcium Oxide (CaO)	62.34
Manganese Oxide (MgO)	3.17
Sulphur Trioxide (SO_3)	2.12
Loss	2.92
Total	97.84

D. Testing of Fine Aggregates (Sand)

The fine aggregate proposed to be used for making mortar cubes and concrete cubes is river sand. River sand is used in this study. The test results of fine aggregates are shown in the following Tables.

Table 7 Test Results of Fineness Modulus of Sand

Test name	Sieve analysis for fine aggregate		
Description of sample	Ayeyarwaddy River Sand		
	Percentage Retained		
Sieve Size	Average Percent Retained	Cumulative Percent	Specified Limits % Retained
4	–	–	0~5
8	2	2	5~15
16	5.4	7.4	10~25
30	27.68	25.08	10~30
50	57.18	92.26	15~35
100	6.42	98.68	12~20
200	0.4	–	2~4
Pan	0.92	–	1~3
F.M	–	2.35	2.2~2.8

Table 8 Test Results of Specific Gravity of Sand

Bottle no.	1	2
Wt. of bottle (W_1) (g)	149.6	153.7
Wt. of bottle + soil (W_2) (g)	696.8	660.5
Wt. of bottle + soil + water (W_3) (g)	1011.8	997.6
Wt. of bottle of water only (W_4) (g)	673.3	684.3
Wt. of soil used ($W_2 - W_1$) (g)	547.2	506.8
Wt. of water used ($W_3 - W_2$)	315	337.1
Wt. of soil ($W_4 - W_1$) - ($W_3 - W_2$) (ml)	208.7	193.5
Specific gravity of soil, $G_s = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$	2.62	2.62

Table 9 Test Results of Absorption of Sand

Container no.	1	2
Wt. of container + wet sand (g)	137	143.2
Wt. of container + dry sand (g)	136	142.3
Wt. of container (g)	33.2	31.3
Wt. of water (W_w) (g)	1	0.9
Wt. of dry sand (W_d) (g)	102.8	111
Absorption = $\frac{W_w}{W_d} \times 100$	0.97	0.81
Average (%)	0.89	

E. Alkaline-Activator

The most used alkaline activators are a mixture of sodium or potassium hydroxide (NaOH, KOH) and sodium silicate or potassium silicate. Mostly sodium hydroxide and sodium silicates (Na_2O=12% and SiO_2 =30 are used in mortar. Since potassium is more expensive than sodium, only sodium is used in this study.

III. Testing of Alkali Activated Slag Mortar

In this study, mixture is prepared to study the effect of activator on the compressive strength of alkali activated slag mortar. The mixture consists of slag, sand, alkali activator and water. The slag is used 250g, cement is used 50g and sand is used 600g for one sample. The variable dosages of alkali activator are used such as 2g (0.67%), 4g (1.3%), 8g (2.67%) and 15g (5%) of slag weight. The weight of water for one sample is 105 ml.

In this test, sand/(slag+cement) of 2 and water/(slag+cement) of 0.35 are used. All the samples are put in the oven without delay time for curing at elevated temperature of 85°C for 24 hours. After curing at elevated temperature, the samples are cured at room temperature until the day of testing. The variable dosages of activator used in alkali activated slag mortar are:

1. NaOH content of 0.67% by weight of slag
2. NaOH content of 1.3% by weight of slag
3. NaOH content of 5% by weight of slag
4. Water glass content of 0.67% by weight of slag
5. Water glass content of 1.3% by weight of slag
6. Water glass content of 5% by weight of slag
7. Water glass and NaOH content of 2.67% by weight of slag
8. Water glass and NaOH content of 5% by weight of slag
9. Without activator in mortar

The summary of compressive strength test results of slag mixed with various alkali activator contents are shown in Table 10 the value of compressive strengths is illustrated in Figure 1.

Table10. Compressive Strength Test Results of Alkali Activated Slag Mortar Mixed with Various Alkali Activator Contents

Activator	Compressive strength (psi)			
	3 days	7 days	14 days	28 days
NaOH 0.67% of slag weight	603.07	683.48	816.46	927.79
NaOH 1.3% of slag weight	402.04	556.68	649.46	819.55
NaOH 5% of slag weight	321.64	389.67	463.89	525.75
Na_2SiO_3 0.67% of slag weight	340.19	422.15	519.56	633.99
Na_2SiO_3 1.3% of slag weight	371.12	510.29	556.68	711.31
Na_2SiO_3 5% of slag weight	535.03	572.14	717.49	835.01
(NaOH +Na_2SiO_3) 2.67% of slag weight	479.36	525.75	587.6	612.34
(NaOH +Na_2SiO_3) 5% of slag weight	386.58	460.8	494.82	556.68
Without activator	296.89	309.26	448.43	504.08

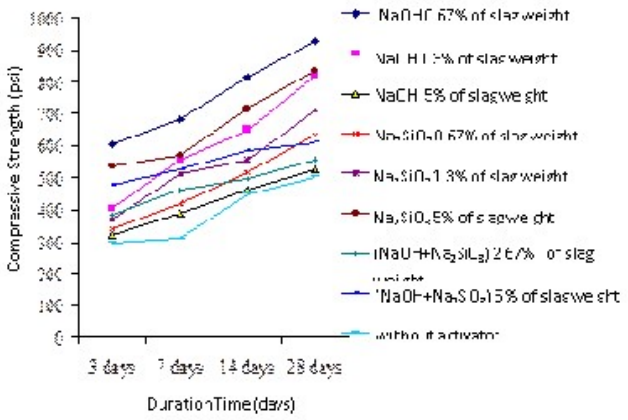

Figure 1 Effect of Dosage of Activator on the Compressive Strength of Alkali Activated Slag Mortar

The compressive strength of alkali activated slag mortar without activator is the lowest and compressive strength of alkali activated slag mortar with NaOH dosage of 0.67% is the highest. In comparison of 3 days strength for NaOH, the strength of NaOH 0.67% of slag weight is the highest and it is also found that the strength of NaOH 0.67% is also the highest in 7 days, 14 days and 28 days strength. When the dosage of NaOH is increased 0.67%, 1.3% and 5%, the strength is decreased in all specified days. In comparison of 3 days strength for Na_2SiO_3, the strength of Na_2SiO_3 5% of slag weight is the highest and it is also found that the strength of Na_2SiO_3 5% of slag weight is also the highest in 7 days, 14 days and 28 days strength. When the dosage of Na_2SiO_3 is increased 0.67%, 1.3% and 5%, the strength is increased in all specified days. In comparison of 3 days strength for (NaOH+Na_2SiO_3), the strength of (NaOH+Na_2SiO_3) 2.67% of slag weight is the highest and it is also found that the strength of (NaOH+Na_2SiO_3) 2.67% is also the highest in 7

days, 14 days and 28 days strength. The strength of alkali activated slag mortar with ($NaOH+Na_2SiO_3$) 2.67% of slag weight is more than that of ($NaOH+Na_2SiO_3$) 5%. The strength of alkali activated slag mortar with activator is more than that without activator. So, the strength of slag mortar with NaOH is increased more than that of water glass.

IV. Testing of Fly Ash Based Geopolymer Mortar

In this study, mixture is prepared to study the effect of activator on the compressive strength of geopolymer mortar. The mixture consists of fly ash, sand, alkali activator and water. The fly ash is used 300g and sand is used 600g for one sample. The variable dosages of alkali activator are used such as 2g (0.67%), 4g (1.3%), 8g (2.67%) and 15g (5%) of fly ash weight. The weight of water for one sample is 100 ml. In this test, sand/fly ash of 2 and water/fly ash of 0.33 are used. All the samples are put in the oven without delay time for curing at elevated temperature of 85°C for 24 hours. After curing at elevated temperature, the samples are cured at room temperature until the day of testing.

The variable dosages of alkali activator used in fly ash based geopolymer mortars are:

1. NaOH content of 0.67% by weight of fly ash
2. NaOH content of 1.3% by weight of fly ash
3. NaOH content of 5% by weight of fly ash
4. Water glass content of 0.67% by weight of fly ash
5. Water glass content of 1.3% by weight of fly ash
6. Water glass content of 5% by weight of fly ash
7. Water glass and NaOH content of 2.67% by weight of fly ash
8. Water glass and NaOH content of 5% by weight of fly ash
9. Without activator in mortar

The summary of compressive strength test results of fly ash mixed with various alkali activator contents are shown in Table 11. The values of compressive strength are illustrated in Figure 1.

Table11. Compressive Test Results of Fly Ash Based Geopolymer Mixed with Various Alkali Activator Contents

Activator	Compressive strength (psi)			
	3 days	7 days	14 days	28 days
NaOH 0.67% of fly weight	556.67	649.46	865.94	1066.96
NaOH 1.3% of fly weight	432.97	572.14	711.31	927.79
NaOH 5% of fly ash weight	293.8	556.68	649.96	717.49
Na_2SiO_3 0.67% of fly ash weight	989.65	1020.6	1051.45	1113.35
Na_2SiO_3 1.3% of fly ash weight	742.23	865.94	927.79	1005.11
Na_2SiO_3 5 % of fly ash weight	550.49	695.85	927.79	989.64
($NaOH+Na_2SiO_3$) 2.67% of fly ash weight	1175.21	1237.1	1267.98	1298.91
($NaOH+Na_2SiO_3$) 5% of fly ash weight	402.04	508.82	732.97	989.65
Without activator	896.86	927.79	1020.57	1113.35

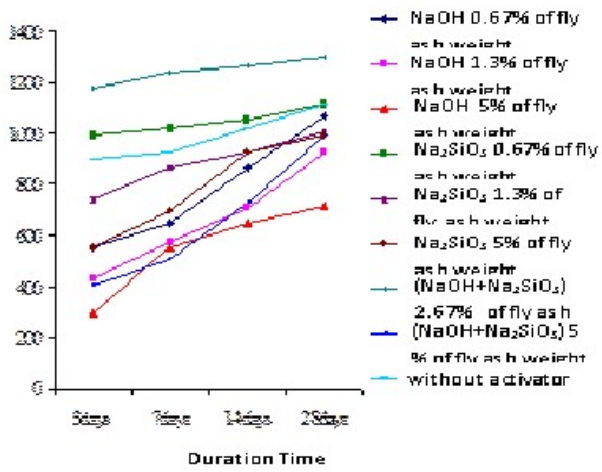

Figure2. Effect of Dosage of Activator on the Compressive Strength of Fly Ash Based Geopolymer Mortar

From this test result, the compressive strength of fly ash based geopolymer mortar with ($NaOH+Na_2SiO_3$) dosage of 2.67% is the highest and with NaOH dosage of 5% is the lowest from those test result. In comparison of 3 days strength for NaOH, the strength of NaOH 0.67% of fly ash weight is the highest and it is also found that the strength of NaOH 0.67% of fly ash weight is also the highest in 7 days, 14 days and 28 days strength. When the dosage of NaOH is increased 0.67%, 1.3% and 5%, the strength is decreased in all specified days. In comparison of 3 days strength for Na_2SiO_3, the strength of Na_2SiO_3 0.67% of fly ash weight is the highest and it is also found that the strength of Na_2SiO_3 0.67% of fly ash weight is also the highest in 7 days, 14 days and 28 days strength. When the dosage of Na_2SiO_3 is increased 0.67%, 1.3% and 5%, the strength is decreased in all specified days.

In comparison of 3 days strength for ($NaOH+Na_2SiO_3$), the strength of ($NaOH+Na_2SiO_3$) 2.67% of fly ash weight is the highest and it is also found that the strength of ($NaOH+Na_2SiO_3$) 2.67% is also the highest in 7 days, 14 days and 28 days strength. When the dosage of Na_2SiO_3 is increased 2.67% and 5%, the strength is decreased in all specified days. The fly ash based geopolymer mortar with activator 2.67% of ($NaOH+Na_2SiO_3$) is more than that without activator. But the compressive strengths of that mortar with 5% of NaOH, $NaOH+Na_2SiO_3$, Na_2SiO_3, 0.67% of NaOH and 1.3% of NaOH, Na_2SiO_3 are less than that of without activator. The fly ash based Geopolymer mortar, Na_2SiO_3 5% of fly ash weight is equal to ($NaOH+ Na_2SiO_3$) 5% of fly ash weight and Na_2SiO_3 0.67% of fly ash weight is equal to without activator in 28 days. So, there is no effect of activator on the strength of fly ash based geopolymer mortar.

V. *Conclusion*

In this study, materials used for mortar are fly ash, slag, alkali activator and sand. Firstly, physical property tests such as fineness test, setting time test, specific gravity test and consistency test are performed for constituents' materials. Alkali activator of sodium hydroxide and water glass are used. In this study, the proportion of mortar is 1:2. Water-fly ash ratio is 0.33; water-(slag cement) ratio is 0.35 and various activator dosages are used to test the compressive strength after 3 days, 7 days, 14 days and 28 days.

In slag mortar, slag cannot be used only because it does not fuse and bind. So, slag has to be mixed with small amount of cement in this study. In slag mortar, the higher dosage of NaOH is used, the lower the compressive strength is obtained and the higher dosage of water glass is used, the more increase the compressive strength of mortar is obtained. In fly ash mortar, the higher dosage of activator is used, the lower the compressive strength of mortar is obtained.

The 28 days compressive strength of slag mortar is the highest when the mortar is mixed with NaOH 0.67% of slag weight in all proportions. It is found that the strength of alkali-activated slag mortar is influenced by NaOH. Activator dosage is effectively influenced on the strength of alkali activated slag mortar. The 28 day compressive strength of fly ash based geopolymer mortar is the highest when the mortar is mixed with 2.67% of (water glass+ NaOH) of fly ash weight in all proportions. It is found that the compressive strength of the fly ash based mortar with and without activator is not much different. So, there is no effect of activator on the strength of fly ash based geopolymer mortar.

REFERENCES

[1] A. Fernández-Jiménez1 A. Palomo2, D. Revuelta3; Alkali Activation of Industrial By-products to Develop New Earth-riendly Cements:1,2,3Eduardo Torroja Institute for Construction Science, (CSIC) Madrid, Spain, 6-9 September 2009, Bath, UK.

[2] Anja Buchwald,Weimar:What are Gopolymer? Current state of research and technology, the opportunities they offer, and their significance for the precast industry,BFT 07/2006

[3] Mark Drechsler, Adelaide, Geopolymers: A New Technology for sustainabilityin Mining, Construction and Hazardous Waste Industries: South Australia, +61 (8) 8405 4300, PB Network #62 February 2006

[4] Louise M.Keyte, Grant C. Lukey and Jannie S.J.van Deventer."The effect of cool ash composition on the properties of waste-based geopolymers. Depertment of chemical and Biomolecular Engineering, The University of Melbourne, Victoria, Australia, ISRS-2004"

[5] Pennsylvania Avenue: Coal Ash; Edison Electric Institute 1701, N.W. Washington, D.C. 20004-2696

[6] S.E. Wallah; B.V. Rangan: Low-calcium fly ash based geopolymer Concrete; Long-term properties. Research report GCI. http://www.geopolymer.org/library/

[7] Josephl. Lawson: on the Determination of the Elastic properties of Geopolymeric Materials: procedding of Master of Science in Mechanical Engineering from the Rochester Institute of Technology Rochester NY.

[8] B. K Paul & R. P Pama, International Ferro cement Information Centre (1978).