CHAPTER III

RESEARCH METHODOLOGY

This research aims to study the influence of the addition of fly ash and cement to improve properties of clayey soil., and how number of optimum contain this addition can be applied to stabilize the clayey soil.

III.1. MATERIALS AND INSTRUMENTS

III.1.1. Materials

1. Soil: clay is taken from Dusun Ngablak, Desa Sitimulyo, Kecamatan Piyungan, Kabupaten Bantul, DIY at 1.5 – 2 m depth. The clay has pass sieve no 4.
2. Cement is Portland Cement (PC) Tiga Roda
3. Fly ash: taken from waste of PLTU Karang Kandri (PT. S2P), Cilacap, Central Java.

III.1.2. Instruments

For clay characteristic test and Unconfined Compression test, it was used apparatus from Soil Mechanics Laboratory of Atma Jaya Yogyakarta University.

1. Sieve no 4.

   It was the sieve that was used to sift the clay that already dried and crushed. The clay that will be used for experiment has to pass this sieve.

2. Oven

   The oven used to dry the clay sample to find out the water content of the clay.

Figure 3.1 Oven

3. Weight scales

   Use the weight scales with sensitivity 0.01gram.

Figure 3.2 Weight Scales

4. Mold

   For Standard Proctor Test, the clay compacted in this cylinder mold with volume 938.1229 cm^3, mold's diameter 10.15 cm, height 11.60 cm.

Figure 3.3 Mold

5. Split Mold Cylinder

   As a tool to mould the sample.

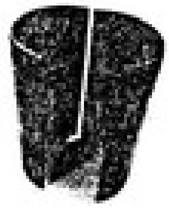

Figure 3.4 Split mold cylinder

6. Hammer

   Also use for clay compaction Standard Proctor Test. Hammer weight 4.273 kg, height of hammer fall 12 inches.

Figure 3.5 Hammer

7. Extruder

   As a tool to release sample from consolidation ring.

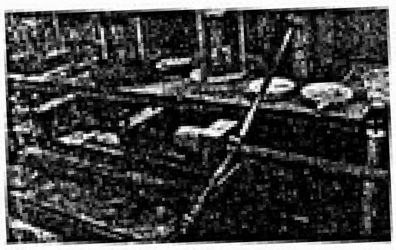

Figure 3.6 Extruder

8. Caliper

   To measure the dimension of the sample.

Figure 3.7 Caliper

9. Unconfined Compression test machine

   As a tool to test the specimen

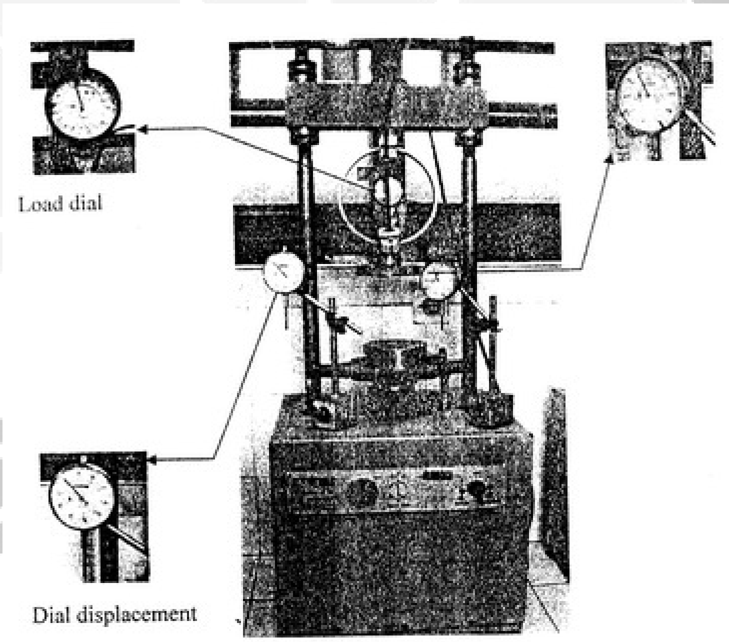

Figure 3.8 Unconfined Compression test machine

III.2. RESEARCH PROCEDURE

III.2.1. Material Test

III.2.1.1. Clay

III.2.1.1.1. Clay Characteristic Test (water content)

The ratio of the weight of water in soil compared to the solid weight. The objective of this test is to investigate the water content of a disturbed soil.

a. Apparatus:

1. Aluminum cup with cover
2. Scale, with sensitivity 0.01 gram
3. Dessicator
4. Oven, able to heathen 105°-110° C

b. Procedure:

1. Empty cup was dried and cleaned. Its weight was noted as W_1.
2. The disturbed soil was filled into the cup half full. The soil was weighed together with the cup and its cover as W_2.
3. The soil was dried in oven at 105°-110° C for 24 hours with its cover was opened and marked to keep it paired with the cup.
4. After dried, it was taken out and cooled in dessicator.
5. The cup containing dried soil was weighed as W_3.

c. Formulas:

Water content:

$$W = \frac{W_2 - W_3}{W_3 - W_1} \times 100\% \qquad (3.1)$$

Where,

W_1 = Weight of empty can

W_2 = Weight of can + wet soil

W_3 = Weight of can + dry soil

W_2-W_3 = Weight of water

W_3-W_1 = Weight of dry soil

III.2.1.1.2. Compaction (Standard Proctor Test)

This test in order to set the optimum moisture content (OMC) of soil. This test performed to compacted clay using compacting method, standard ASTM D698-78.

a. Apparatus:

1. Sieve No. 4
2. Mold, to compact the clay
3. Standard compactor
4. Extruder
5. Scale, with sensitivity 0.1 gram
6. Spatula and stick mate
7. Oven, adjustable for 105°-110° C
8. Caliper
9. Water content cup

b. Procedure:

1. The clay was crushed and sieved using No. 4 and it was made into 6 samples, 2.5 kg each.
2. Each of the samples was added with water, as much as 100 ml, 200 ml, 300 ml, 400 ml, 500 ml, and 600 ml. They were put into separate plastic bags and were left for 24 hours.
3. The main cylinder was cleaned, weighed and recorded. The dimensions were taken.
4. The collar and the cylinder were fixed and the inner surface was lubricated using used oil to ease extruding soil from cylinder.
5. Each sample was compacted by filling it to the cylinder into 3 layers. The compaction pattern followed the standard soil compaction method.
6. The main cylinder was separated from the collar. The upper part was trimmed. After weighed, the soil sample was extruded. It was sampled from its core and its water content was tested.
7. These steps were repeated for all samples.

c. Formulas:

1. Unit weight of soil:

$$\gamma_b = \frac{W_1 - W_2}{V} \qquad (3.2)$$

Where,

W_1 = Weight of cylinder + dense soil

W_2 = Weight of cylinder

V = Volume

2. Unit weight of dry soil:

$$\gamma_d = \frac{\gamma}{1+w} \qquad (3.3)$$

Where,

γ = Unit weight of soil

w = Moisture content

3. Optimum Moisture Content (OMC):

$$Amount\ of\ Water = \frac{OMC - w}{100 - w} \times 5000 \qquad (3.4)$$

Where,

OMC = Optimum Moisture Content

w = Average water content

III.2.1.2. Fly Ash (chemical and mineralogy test)

These test in order to figures the chemical composition of fly ash. Main component of fly ash: silica (SiO_2), alumina (Al_2O_3), and ferrite oxide (Fe_2O_3), the rest are carbon, calcium, magnesium, and sulfur. Fly ash empirical formula: $Si_{1.0}Al_{0.45}Ca_{0.51}Na_{0.047}Fe_{0.039}Mg_{0.020}K_{0.013}Ti_{0.011}$.

The data was taken from fly ash source factory (PLTU Cilacap). The content of SiO_2+Al_2O_3+Fe_2O_3 from fly ash is 66.46%. Based on ASTM C618-80, this fly ash include to Class C type. This type of fly ash has pozzolan characteristic and when it's mixed with water, it will become hard caused by hydration.

III.2.2. Sample Preparation and Production

III.2.2.1. Sample Preparation

1. The clay was crushed and sieved using No.4, and it was made into 10 samples, 2.5 kg each.
2. Make several combination of clay + cement, clay + cement + fly ash, depend the percentage each of them. For each combination we make it into 3 separate plastic bags (for 3 times of curing time), except for the clay+cement test (only using one time of curing time).

Figure 3.9 Clay + fly ash mixing

3. Each of the samples was added with water as much as volume of optimum moisture content get. then left it for 24 hours.

Figure 3.10 Sample on plastic bag

III.2.2.2. Sample Production

1. The main cylinder was cleaned. The collar and the cylinder were fixed, and the inner surface was lubricated using used oil to ease extruding clay from cylinder.
2. Each sample was compacted by filling it to the cylinder into 3 layers. The compaction pattern followed the standard soil compaction method.

Figure 3.11 Sample compaction

3. The main cylinder was separated from the collar. The upper part was trimmed.
4. Split mold cylinder was cleaned, and lubricated using used oil to ease extruding sample from cylinder mold.
5. Put the split mold cylinder mold into the upper part of cylinder mold. Push the split mold cylinder mold with extruder to the cylinder, in order to get sample for UCS test.
6. Make sure that all part of split mold cylinder has been entering the cylinder, and the sample full fill the split mold cylinder.
7. Pull out the split mold cylinder from cylinder with extruder.
8. Pull out the sample carefully from the split mold cylinder.
9. These steps were repeated for all samples.

Table 3.1 Total sample for UCS test

Composition	0%	8%	12%	16%	24%	36%	Sub-total
Clay + Cement…%	1	1	1	1			4
Clay + Cement + Fly Ash….%	3		3		3	3	12
TOTAL							16

III.2.3. Curing Time

Curing time needed to compare the result from each variable on the different time period. In this research, the writer takes 3 periods of curing time, which are 0, 7, and 14 days. During the curing time, the samples were left in free air condition without special treatment, in order to approach the real condition on the field.

III.2.4. Unconfined Compression (UCS) Test

After the material test, the test advanced with addition of fly ash on clay which is followed by mechanical characteristic test. For the mechanical test, the writer use Unconfined Compression test.

a. Apparatus

1. Compression apparatus
2. Extruder
3. Strain dial
4. Stress dial
5. Split mold cylinder
6. Scale, with 0.1 sensitivity
7. Caliper
8. Saw
9. Arch

b. Procedure

1. The specimen was placed on a metal plate vertically and placed centered on the base plate of compression apparatus.
2. The compression machine was adjusted so that the top plate would just touch the top of the specimen.
3. All dials were set to zero.
4. He compression machine was started.
5. The stress dial was read for every 25 increment read on strain dial.
6. The loading was stopped when the stress dial showed the same number or decreasing for three consecutive times.
7. The specimen was taken off the machine.
8. The shear angle, or the failure angle, was measured.

c. Formulas:

$$\Phi = (\alpha - 45°) \times 2$$

$$q_u = 2.c.tg\,(45 + ½\,\Phi)$$

Where,

D = Diameter (cm)

Lo = Height (cm)

B = Weight (gram)

Ao = Initial cross section area (cm^2)

V = Volume (cm^3)

γ = Unit weight ($gram/cm^3$)

α = failure angle (°)

Φ = Inner shear angle (°)

c = Cohesive value (kg/cm^2)

q_u = Shear strength (kg/cm^2)

III.3. RESEARCH FLOW CHART

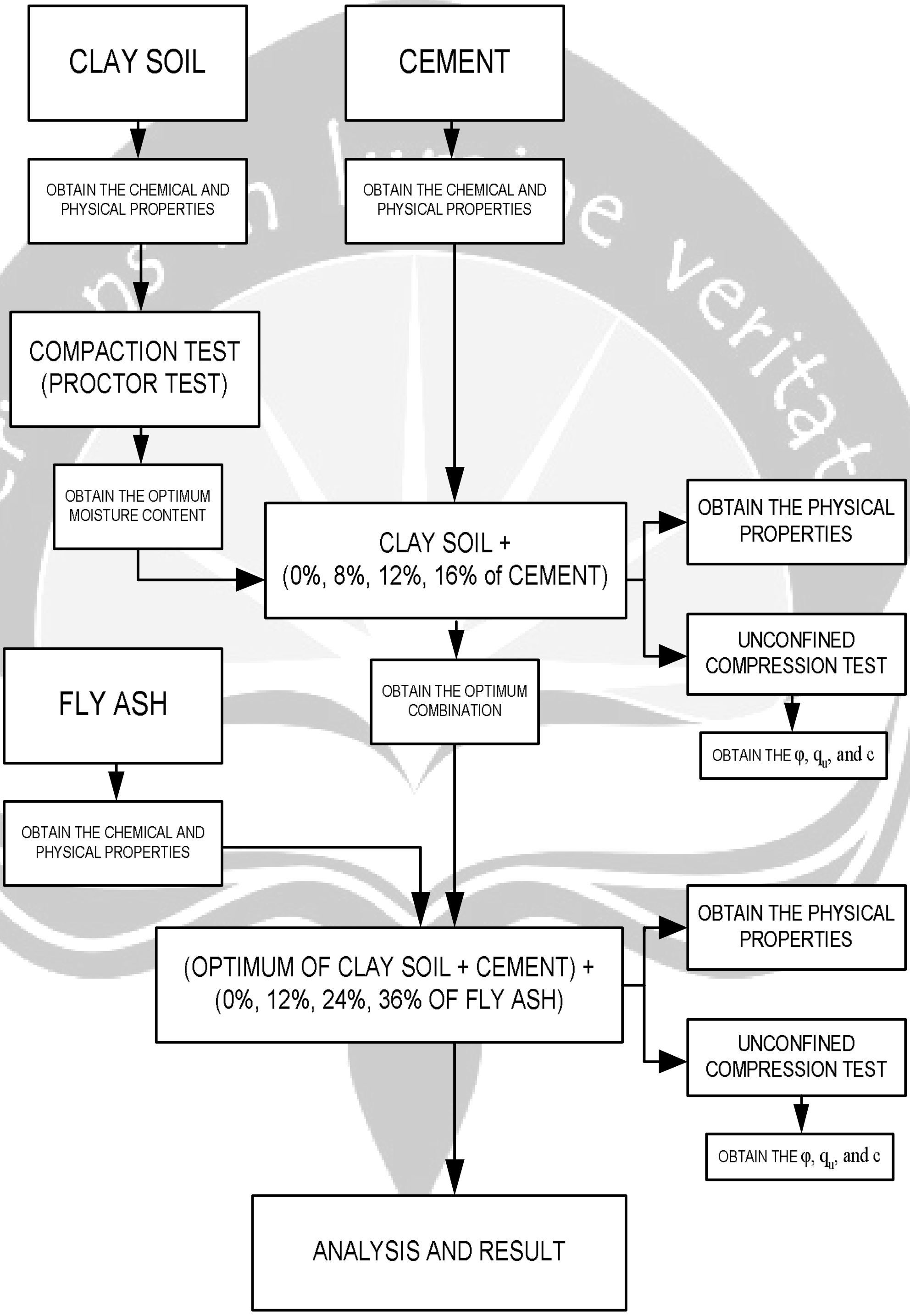

Figure 3.12 Research Flow Chart

CHAPTER IV

RESULT AND ANALYSIS

IV.1. MATERIAL TEST RESULT

It is an initial test for the material before triaxial test. The material test results include the result of fly ash and clay characteristic test.

IV.1.1. Clay Characteristic Test Result (water content)

In this test, the clay sample separated into 2 aluminum cups to get the average water content of the clay. The complete result of this test concluded in table 4.1.

From table 4.1, water content of the first sample is 18.01%, and from the second sample is 17.05%. The average water content of the clay sample is 17.53%. The average water content of clay will be used to find out the optimum moisture content of clay in the proctor test.

Table 4.1 Water content test

1	Sample number		2.40	2.41
2	Weight of can	W_1 gram	14.45	14.20
3	Weight of can + wet soil	W_2 gram	57.05	56.55
4	Weight of can + dry soil	W_3 gram	50.55	50.38
5	Weight of water	$(W_2 - W_3)$ gram	6.5	6.17
6	Weight of dry soil	$(W_3 - W_1)$ gram	36.1	36.18
7	Water content	$w = \frac{W_2 - W_3}{W_3 - W_1} \times 100\%$	18.01%	17.05%
8	Average water content			17.53%

IV.1.2. Standard Proctor Test Result

Compaction method used in this standard proctor test, with sample volume is 938.1229 cm^3 (diameter = 10.15 cm; height = 11.60 cm), hummer weight = 4.273 kg, 3 layers of clay with 25 blows for each layer. The clay sample separated into 6 plastic bags, and added with water as much as 100 ml, 200 ml, 300 ml, 400 ml, 500 ml, and 600 ml. With the water addition, the unit weight of soil is increased. Table 4.2 and figure 4.1 shows the relationship between unit weight and water addition.

Table 4.2 Unit weight

Test no	2.100	2.200	2.300	2.400	2.500	2.600
Weight of cylinder + dense soil, gram (W_1)	3558	3654	3717	3741	3777	3793
Weight of cylinder, gram (W_2)	2269	2269	2269	2269	2269	2269
Weight of dense soil, gram (W_1-W_2)	1289	1385	1448	1472	1508	1524
Unit weight, $\gamma = \frac{W_1 - W_2}{V}$	1.3740	1.4764	1.5435	1.5691	1.6075	1.6245

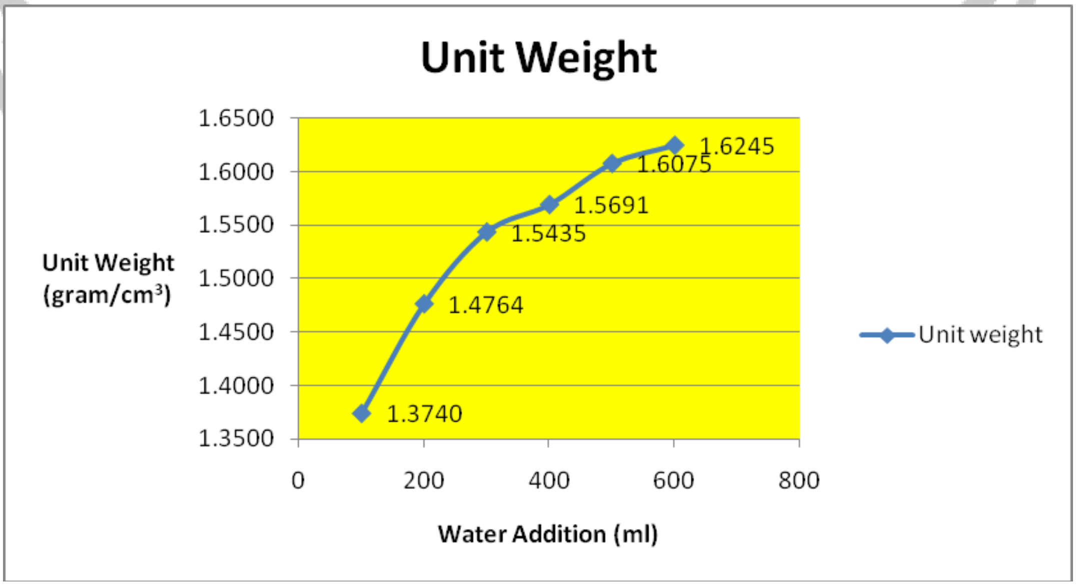

Figure 4.1 Unit weight after water addition

Table 4.2 and figure 4.1 shows that with the addition of water, the unit weight of clay will increase. By 100 ml water addition, the clay unit weight is 1.3740 gram/cm^3; 200 ml water addition, the unit weight increase to 1.4764 gram/cm^3; 300 ml water addition, unit weight 1.5435 gram/cm^3; 400 ml water addition, unit weight 1.5691 gram/cm^3; 500 ml water addition, unit weight 1.6075 gram/cm^3; and 600 ml water addition, unit weight 1.6245 gram/cm^3.

After the calculation of unit weight, the next step is OMC calculation. For OMC calculation, take some clay from each sample that already performs compaction, in order to set the average moisture content and weight of dry volume. Separate each sample into 2 tin boxes, so there are 12 tin boxes that will be keep in the oven for at least 24 hours. Before keep in the oven, take weight measurement first for both empty tin box and the tin boxes filled with clay. The complete data and the calculation shows in table 4.3.

Table 4.3 Data for OMC calculation

No. tin box		1	2	3	4	5	7	8	13	14	16	19	20
Weight empty tin box	W_1, gram	24.00	24.64	24.05	24.29	23.68	24.65	23.09	24.02	24.58	23.49	23.49	23.49
Weight tin box + wet soil	W_2, gram	65.60	64.75	67.30	69.65	60.80	65.30	58.75	60.85	57.80	63.70	65.25	62.35
Weight tin box + dry soil	W_3, gram	58.44	57.93	58.19	60.31	51.89	55.83	49.80	51.61	48.61	52.70	53.04	50.76
Weight water	$A = (W_2 - W_3)$ gram	7.16	6.82	9.11	9.34	8.91	9.47	8.95	9.24	9.11	11	12.21	11.59
Weight dry soil	$B = (W_3 - W_1)$ gram	34.44	33.29	34.14	36.02	28.21	31.18	26.71	27.59	24.03	29.21	29.55	27.27
Moisture content	$w = \frac{A}{B} \times 100\%$	20.79	20.47	26.68	25.93	31.58	30.37	33.51	33.49	38.24	37.66	41.32	42.50
Average moisture content, %		20.64		26.31		30.98		33.50		37.95		41.91	
Weight dry volume, $\gamma_d = \frac{\gamma}{1+w}$		1.1390		1.1689		1.1784		1.1754		1.1652		1.1448	

Table 4.3 shows that the average moisture content and weight dry volume of clay from each samples (6 samples), with various water content addition (100 ml; 200 ml; 300 ml; 400 ml; 500 ml; and 600 ml). First sample with 100 ml water addition (tin box no. 1 and 2), the average moisture content is 20.64%, weight dry volume (γ_d) is 1.1390 gram/cm^3; second sample with 200 ml water addition (tin box no. 3 and 4), average moisture content = 26.31%, γ_d = 1.1689 gram/cm^3; third sample with 300 ml water addition (tin box no. 5 and 7), average moisture content = 30.98%, γ_d = 1.1784 gram/cm^3; fourth sample with 400 ml water addition (tin box no. 8 and 13), average moisture content = 33.50%, γ_d = 1.1754 gram/cm^3; fifth sample with 500 ml water addition (tin box no. 14 and 16), average moisture content = 37.95%, γ_d = 1.1652 gram/cm^3; sixth sample with 600 ml water addition (tin box no. 19 and 20), average moisture content = 41.91%, γ_d = 1.1448 gram/cm^3.

From the data above, figure 4.2 shows the relationship between average moisture content and dry density volume.

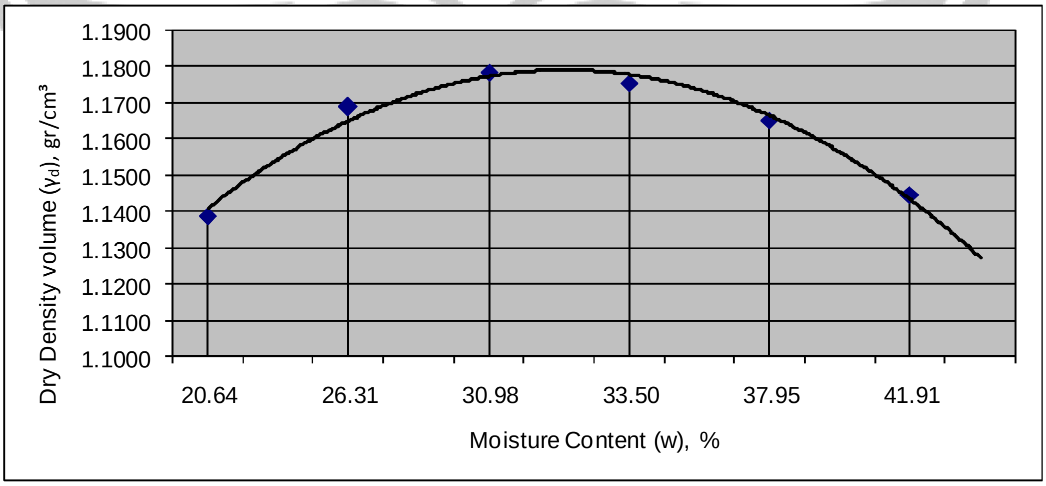

Figure 4.2 Average moisture content and dry density volume (γ_d)

From the figure above, the amount of maximum dry density (MDD) is 1.18 gram/cm^3, and optimum moisture content (OMC) is 32.24%. Based on the MDD and OMC, the water content for OMC condition can be calculated. By the calculation the result is 901.54 ml water needed for OMC condition.

IV.2. UNCONFINED COMPRESSION TEST (UCS) RESULT

IV.2.1. Clay Soil + Cement

For complete result of these UCS test please see the appendix. The figures below shows the values of friction angle (Φ), cohession (c), and shear strength (q_u) of clay + cement from various samples (0%; 8%; 12%; and 16%) of cement, with one curing time (0 day).

Table 4.4 UCS test of Clay – Cement result conclusion

CEMENT	ϕ	q_u	c
%	(°)	(kg/cm2)	(kg/cm2)
0%	10	0.2390	0.1003
8%	40	0.7649	0.1783
12%	30	0.2043	0.0590
16%	20	0.1187	0.0416

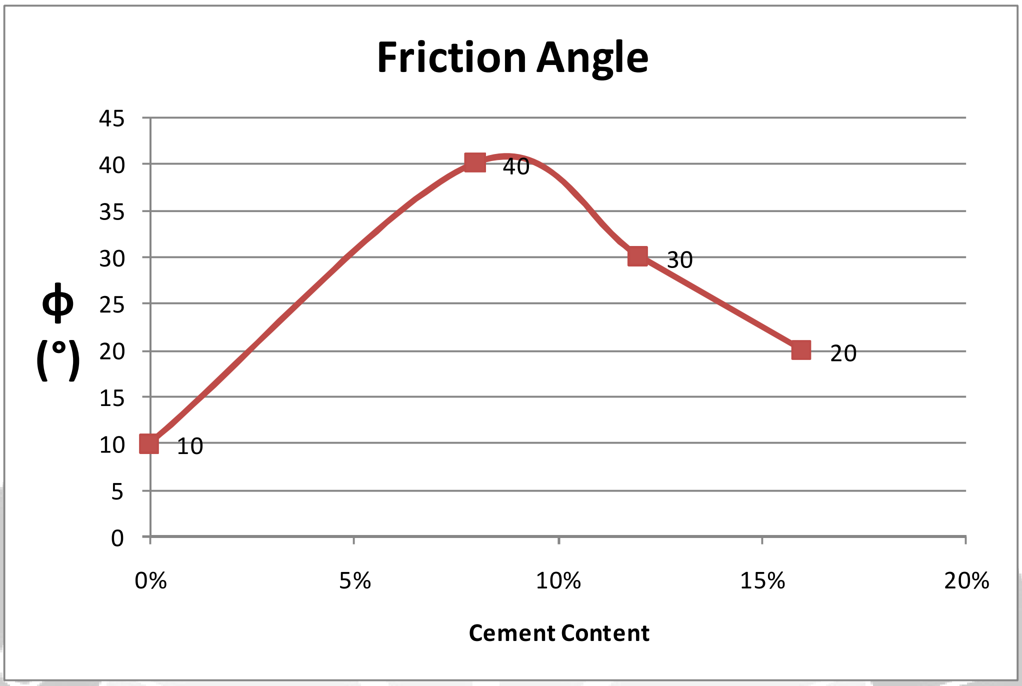

Figure 4.3 Friction Angle Value of Clay – Cement

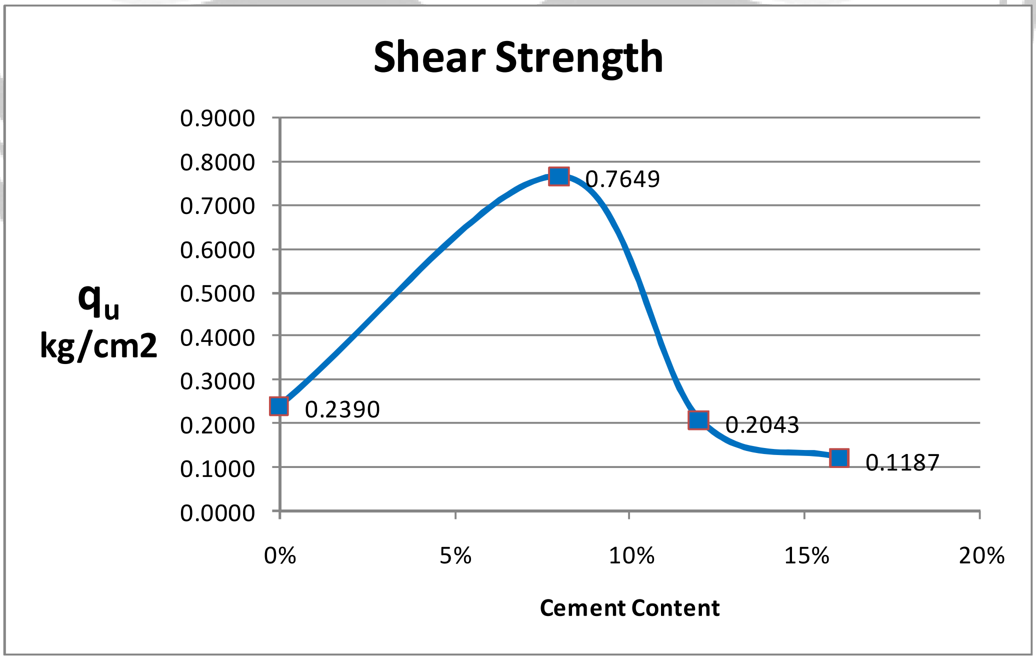

Figure 4.4 Shear Strength Value of Clay – Cement

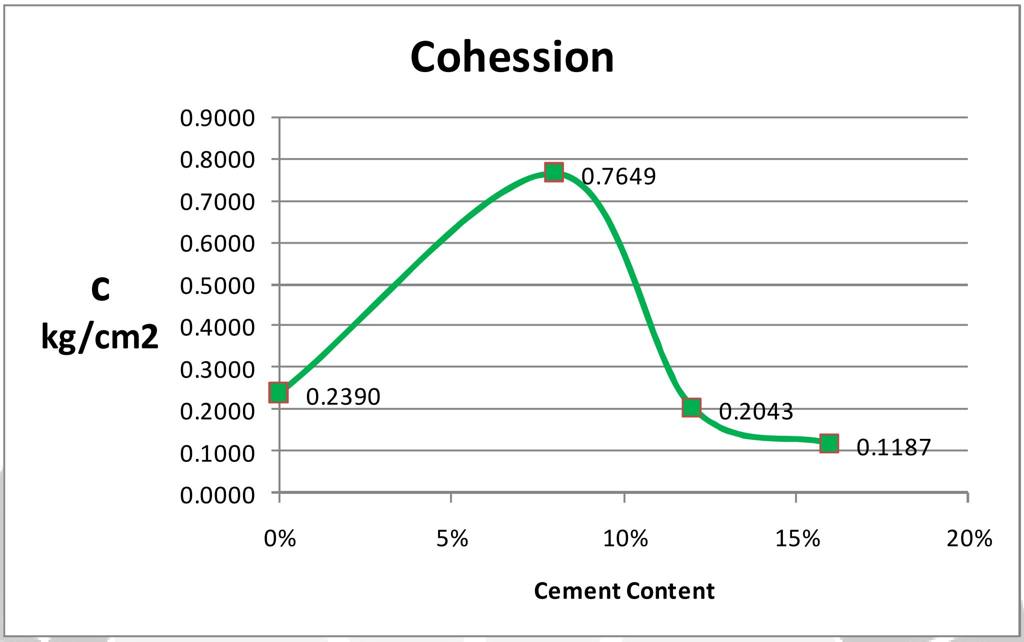

Figure 4.5 Cohession of Clay – Cement

From table 4.4, figure 4.3, 4.4, 4.5, obtained that cement at percentage 8% is the best value of these combination. The values of c and q_u at 8% of cement are increased compare with 0% of cement, but then decreased at the percentage values above 8%.

So, obtain the optimum percentage of cement is 8% to enter the next combination of clay, cement, and fly ash.

IV.2.2. Clay Soil + Cement + Fly Ash

For complete result of these UCS test please see the appendix. The figures below shows the values of friction angle (Φ), cohession (c), and shear strength (q_u) of clay + cement + fly ash from various samples (0%; 8%; 12%; and 16%) of fly ash, with three times curing time (0, 7, and 14 days). Here, we used cement at percentage of 8%, obtained from the conclusion of subchapter above, where this percentage of cement have the optimum values of cohession and shear strength.

Table 4.5 UCS test of Clay – Cement – Fly Ash result conclusion

CEMENT	FLY ASH	DAY	ϕ	q_u	c
%	%		(°)	(kg/cm2)	(kg/cm2)
8%	0%	0	10	1.6095	0.6753
		7	20	2.0822	0.7290
		14	20	2.3199	0.8122
	12%	0	20	2.1988	0.7698
		7	30	2.7664	0.7986
		14	30	3.1633	0.9132
	24%	0	30	1.8028	0.5204
		7	30	1.9819	0.5721
		14	30	2.1695	0.6263
	36%	0	30	1.2240	0.3533
		7	40	1.6327	0.3807
		14	20	1.7194	0.6020

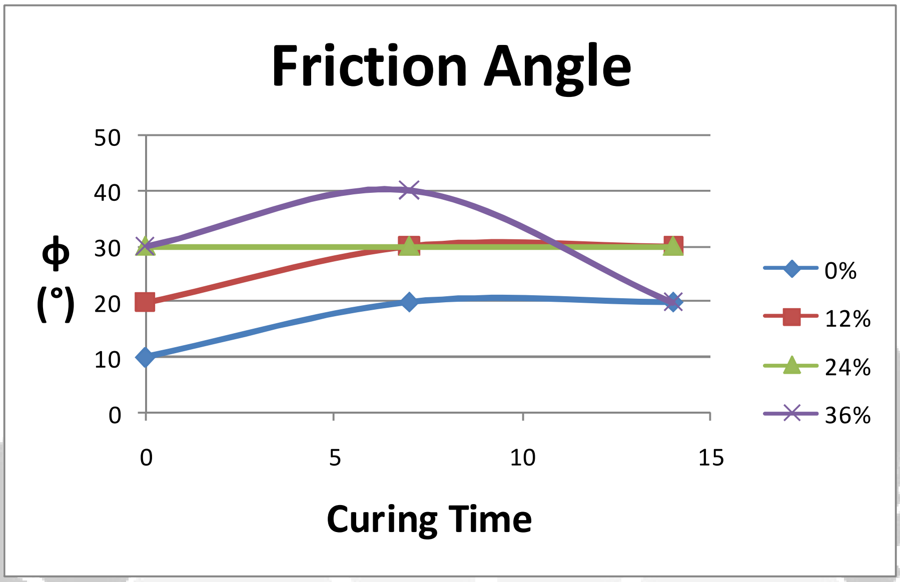

Figure 4.6 Friction Angle Value of Clay – Cement – Fly Ash

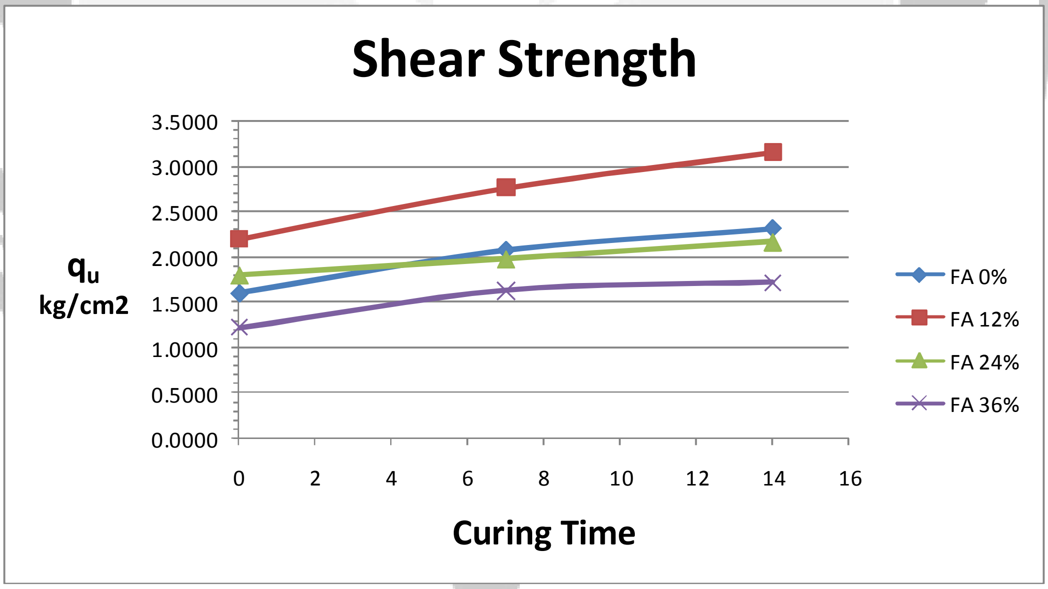

Figure 4.7 Shear Strength Value of Clay – Cement – Fly Ash

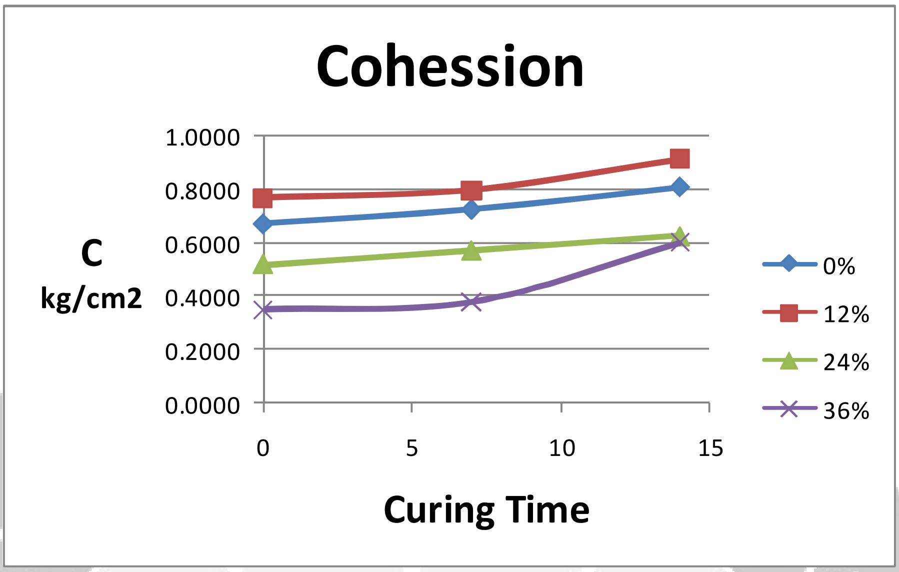

Figure 4.8 Cohession of Clay – Cement – Fly Ash

The pattern above shows the increment of shear strength and cohession along the curing time. The amount of fly ash added will also influence the shear strength and cohession. With 12% addition of fly ash, the shear strength and cohesion is the biggest than another combination of fly ash; with 24% and 36% addition of fly ash, founded that the values of shear strength and cohesion, although its increased along the curing time, it have lower value than 12 % addition of fly ash, even it lower than no addition (0%) of fly ash.