JOS - MRK *Volume 6, Nomor 1, Maret 2025, Page 149-156*

JURNAL ONLINE SKRIPSI
MANAJEMEN REKAYASA KONSTRUKSI POLINEMA

Journal homepage: http://jurnal.polinema.ac.id/ **ISSN: 2722-9203 (media online/daring)**

THE IMPACT OF ASBESTOS WASTE ADDITION ON SOIL FOR SHALLOW FOUNDATION UNDER TRIAXIAL TESTING

Grachia O. V. Simanjuntak[1], Dandung Novianto[2], Marjono[3]
Construction Engineering Management Student[1], Civil Engineering Lecturer[2], Civil Engineering Lecturer[3]
Email: *grachiaoctaviana@gmail.com[1]*, *dandung.novianto@polinema.ac.id[2]*, *marjonots2020@gmail.com[3]*

ABSTRACT

Soil with high swelling and shrinkage properties has a low shear strength value. Such soil is certainly dangerous if used as a foundation for buildings. This research article presents asbestos waste as an alternative soil stabilizer because of the magnecium-calcium-silicat that can be used as a binder and also as a filler to fill the voids in the soil. The value of the soil shear strength parameters can be obtained from the Triaxial Unconsolidated Undrained test. The percentages of asbestos waste used are 3%, 6%, and 9% with curing periods of 0, 1, and 14 days. The results of the research show that the original soil is classified according to the USCS method as SP-SC soil with plasticity index(PI) value is 21,73%. After conducting the triaxial test on the original soil, the original soil cohesion value is 0,12 kg/cm² and the internal friction angle is 11,20°. After stabilization with several variations, it was found that the addition of asbestos waste affects the plasticity index, cohesion, and internal friction angle. Adding 9% of asbestos waste gives the maximum value of plasticity index which is 9,58%. Adding 6,37% asbestos waste with 14 days of curing provides the most optimum cohesion achieved is 0,46 kg/cm² and internal friction angle value is 27,3°. The maximum load produced by one column (Qv) is 88,80 ton, and the highest allowable loads(Qall) is 108,89 ton using a rectangular-shaped foundation(1,00 x 1,50) meter dimension. The stabilization process involved manually mixing the soil and asbestos beneath the foundation. Therefore, stabilization using asbestos waste is quite effective.

***Keywords** : Soil Classification; Soil Parameter; Shallow Foundation; Implementation Method; Cost Estimation*

1. INTRODUCTION

Expansive soil is soil that has a high swelling-shrinkage capability due to changes in moisture content. Soil with a high swelling-shrinkage rate has a greater potential for soil displacement. The swelling-shrinkage value will significantly affect the structures built on it, such as foundations. A high swelling-shrinkage rate can cause cracks in buildings, uneven movement, or even structural collapse. When the soil is subjected to loading, it will be resisted by the soil's cohesion value and internal friction angle. The soil's cohesion value depends on the type of soil but is not influenced by the normal stress acting on the shear plane. The internal friction angle of the soil is directly proportional to the normal stress on the shear plane.

The value of soil shear strength parameters can determine soil stability. Soil with a high cohesion value is considered stable (Setyawan, 2007). The Unconsolidated Undrained Triaxial test is one of the tests conducted to obtain soil shear strength parameters, as this test provides values for cohesion and soil internal friction angle.

Asbestos contains magnesium-calcium-silicate, which is physically very strong. The chemical composition of asbestos gives it binding properties that can stabilize soil. Malang city has an asbestos factory whose waste has not been maximally processed, raising concerns about pollution caused by untreated asbestos waste, which hasn't been properly utilized or increased in economic value.

In an effort to utilize waste, researchers aim to study the impact of asbestos waste on soil shear strength parameters. The researchers have titled their study "The Impact of Asbestos Addition on Soil for Shallow Foundation under Triaxial Testing."

2. METHOD

This research was conducted in the laboratory of the State Polytechnic of Malang. The soil sample is taken from Jl. Patimura Gg. V RT. 05 RW. 06 Kelurahan Temas Batu, East Java. This research is a quantitative experimental, because the purposes of this test is to measure and determine numerical value of soil properties and involves manipulationg dependent variables (such as volume of asbestos waste and duration of curing day) to observes their effect on the dependent variable (consistency limit, soil bearing capacity, soil shear strength, and soil consolidation). This research use variation of asbestos addition 3%, 6%, and 9% with curing day for each variation 0, 1, and 14 days.

The following are the standards used in the testing:

1. Water content (ASTM D2216)
2. Unit weight (ASTM S7265)
3. Soil Specific Gravity (ASTM D854)
4. Mechanical Sieve Analysis (ASTM C136:2012)
5. Hydrometer Analysis (ASTM D2216)
6. Consistency Limit (ASTM D4218)
7. Unconsolidated Undrained Triaxial (ASTM D2850-87)
8. Consolidation Testing (ASTM D2435-90)

Thus, with the values of cohesion and internal friction angle, the soil bearing capacity can be calculated using the Terzaghi method. Terzaghi's bearing capacity analysis is based on the assumption of general shear failure, as proposed by Terzaghi (1943), which assumes that the foundation is infinitely long and has a width B, situated on a homogeneous soil.

1. General Shear Failure for circle footing with width radius R

   $q_u = 1{,}3.c.N_c + \gamma.D_f.N_q + 0{,}6.\gamma.R.N_\gamma$

2. General Shear Failure for square footing with width B

   $q_u = 1{,}3.c.N_c + \gamma.D_f.N_q + 0{,}4.\gamma.B.N_\gamma$

3. General Shear Failure for rectangle footing with width B x l

   $q_u = c.Nc.(1 + 0{,}3\ B/L) + \gamma.Df.Nq + ½.\gamma.B.N\gamma\ (1 – 0{,}2.B/L)$

Therefore, the flowchart of this research can be outlined as follows:

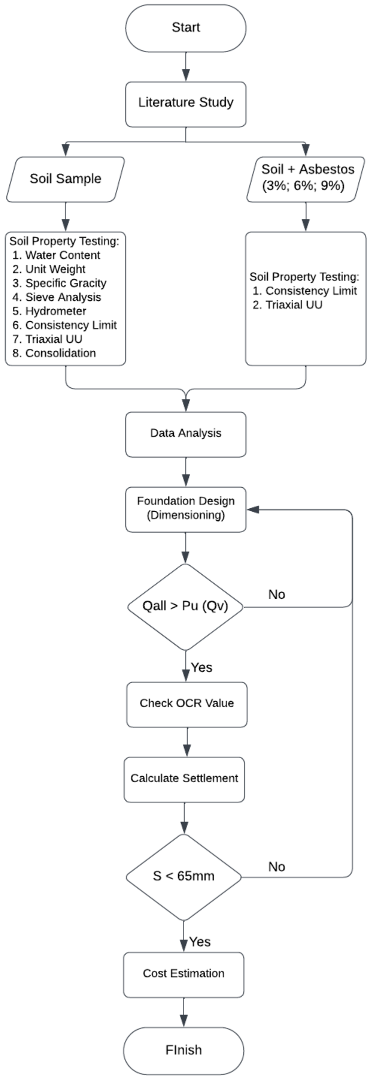

Figure 1 Research Flowchart

3. RESULT AND DISCUSSION

Original Soil Testing

From the test results, the soil passing through the No. 200 sieve is 5,83%, and the soil passing through the No. 4 sieve is 99,88%, with Cu = 8,804 and Cc = 0,773. The parameters obtained include a Liquid Limit (LL) of 45,80%, a Plastic Limit (PL) of 24,07%, and a Plasticity Index (PI) of 21,73%. Based on the Unified Soil Classification System (USCS) method, the soil is classified as SP-SC (Poorly-graded sand with clayey sand).

Tabel 1 Soil Testing Result

Parameter	Symbol	Unit	Testing Result
Water Content	w	%	41,86
Soil Unit Weight	γ_{wet}	gr/cm^3	1,75
Soil Specific Gravity	Gs		2,61
Mechanical Sieve Analysis			
Gravel		%	0,12
Sand		%	94,05
Silt		%	3,45
Clay		%	2,39
Uniformity Coefficient	Cu		8,80
Coefficient of Gradation/Curvature	Cc		0,77
0% Liquid Limit	LL	%	45,80
Plastic Limit	PL	%	24,07
Plasticity Index	PI	%	21,73
3% Liquid Limit	LL	%	50,27
Plastic Limit	PL	%	33,43
Plasticity Index	PI	%	16,84
6% Liquid Limit	LL	%	52,40
Plastic Limit	PL	%	36,28
Plasticity Index	PI	%	16,12
9% Liquid Limit	LL	%	52,98
Plastic Limit	PL	%	43,31
Plasticity Index	PI	%	9,58
Soil Classification based on USCS			SP-SC
Cohesion	C	kg/cm^2	0,12
Internal Soil Friction	ϕ	°	11,20
Compression Index	Cc		0,53
Overconsolidated Ratio	OCR		0,28
Soil Type			NC-Soil

After stabilization using asbestos waste with varying percentages and curing times, the PI value of the original soil can be reduced. Based on **Tabel 1,** the addition of asbestos waste can increase the liquid limit and decrease the plasticity index of the original soil.

Original Soil with Addition of Asbestos Waste Shear Strength

The addition of asbestos waste affects the values of cohesion and internal friction angle shown at **Tabel 2**

Tabel 2 Cohesion Value and Internal Fraction Angle of Stabilized Soil

Composition	Curing (day)	Cohesion (kg/cm^2)	Internal Friction Angle (°)
Soil + 3% Asbestos Waste	0	0,14	11,63
	1	0,23	14,47
	14	0,14	21,17
Soil + 6% Asbestos Waste	0	0,15	13,14
	1	0,27	18,20
	14	0,46	27,29
Soil + 9% Asbestos Waste	0	0,15	13,40
	1	0,25	15,49
	14	0,29	21,77

Effect of Stabilization Using Asbestos Waste

This data analysis employs linear regression methods, including the coefficient of determination (R^2), to quantify the influence of asbestos content on the soil's shear angle and cohesion values. The coefficient of determination indicates how well the independent variable (asbestos content) explains the variability of the dependent variables (shear angle and cohesion). A higher R^2 value suggests a stronger relationship between these variables.

1. 0 Day of Curing

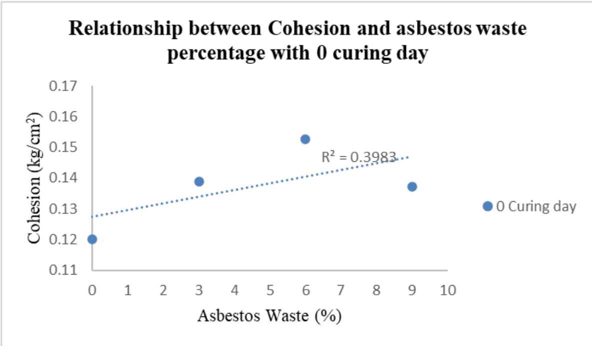

Figure 2 The relationship between percentage of asbestos waste content and cohesion value with 0 curing day

Based on the analysis at **Figure 2**, the R square value is 0,40. It means the content of asbestos waste influence 39,83% of cohesion value, and the other 60,17% is influence by other variables.

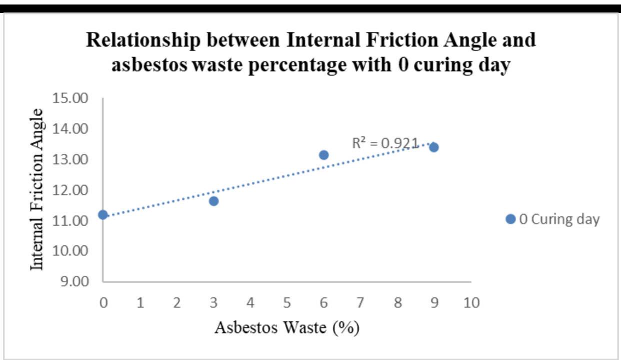

Figure 3 Relationship between internal friction angle and asbestos percentage with 0 curing day

Based on the analysis at **Figure 3**, the R square value is 0,92. It means the content of asbestos waste influence 92,1% of internal friction angle value, and the other 7,9% is influence by other variables.

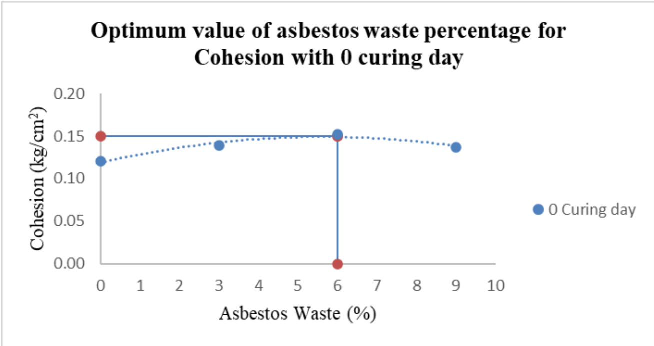

Figure 4 Optimum Value of asbestos waste percentage for Cohesion with 0 curing day

From the **Figure 4** above, From the graph showing the relationship between the percentage of asbestos and cohesion values with 0 days of curing, it was found that the maximum value was 0,15 with an optimum asbestos mixture composition of 6%.

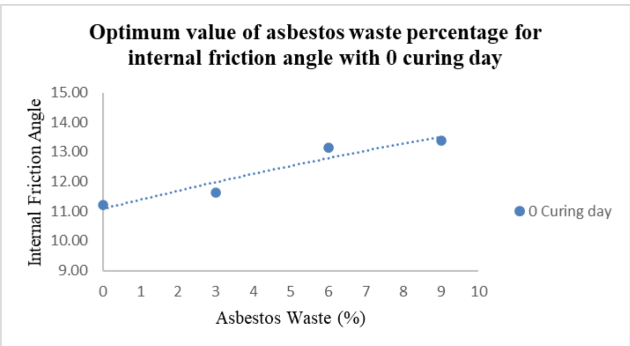

Figure 5 Optimum value of asbestos waste percentage for internal friction angle with 0 curing day

From the **Figure 5** above, From the graph showing the relationship between the percentage of asbestos and internal friction angle values with 0 days of curing, an optimal mix ratio for this mixture could not be determined due to the continually increasing internal friction angle.

2. 1 Day of Curing

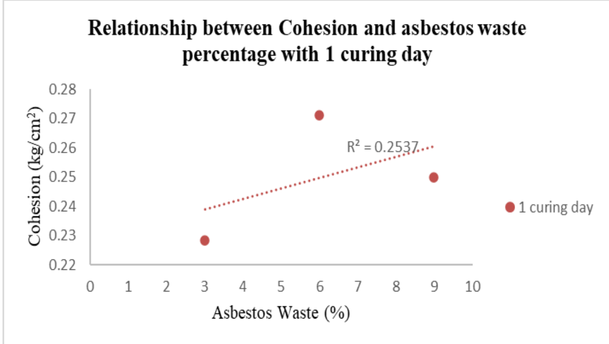

Figure 6 Relationship between Cohesion and asbestos waste percentage with 1 curing day

Based on the analysis at **Figure 6**, the R square value is 0,2537. It means the content of asbestos waste influence 25,37% of cohesion value, and the other 74,63% is influence by other variables.

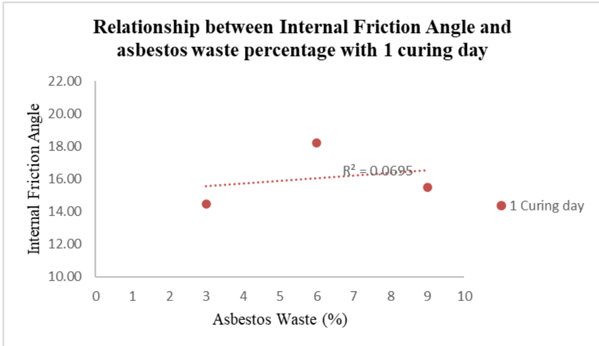

Figure 7 Relationship between Internal Friction Angle and asbestos waste percentage with 1 curing day

Based on the analysis at **Figure 7**, the R square value is 0,07. It means the content of asbestos waste influence 6,95% of internal friction angle value, and the other 93,05% is influence by other variables.

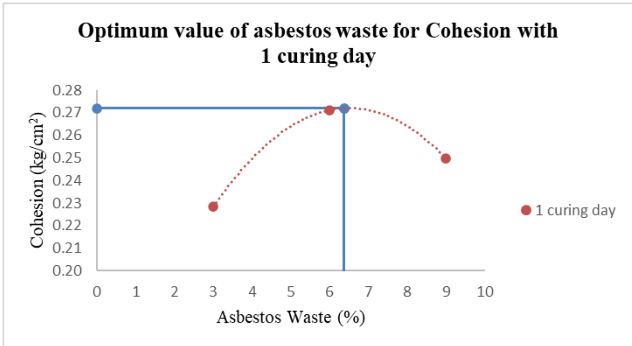

Figure 8 Optimum value of asbestos waste for Cohesion with 1 curing day

From the **Figure 8** above, From the graph showing the relationship between the percentage of asbestos and cohesion values with 1 days of curing, it was found that the maximum value was 0,27 with an optimum asbestos mixture composition of 6,37%.

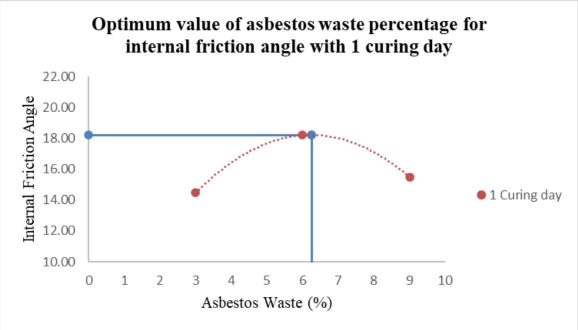

Figure 9 Optimum value of asbestos waste percentage for internal friction angle with 1 curing day

From the **Figure 9**, the graph showing the relationship between the percentage of asbestos and internal friction angle values with 1 day of curing, it was found that the maximum value was 18,2 with an optimum asbestos mixture composition of 6,25%.

3. 14 Day of Curing

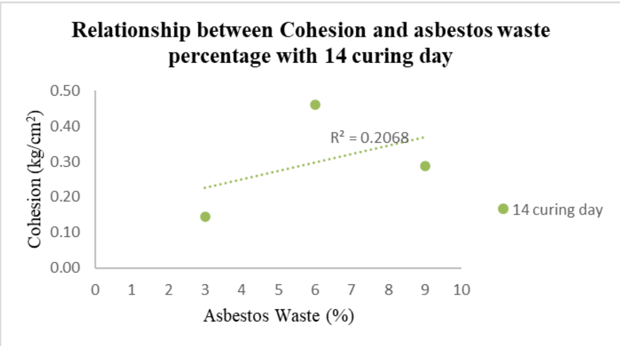

Figure 20 Relationship between Cohesion and asbestos waste percentage with 14 curing day

Based on the analysis at **Figure 10**, the R square value is 0,2068. It means the content of asbestos waste influence 20,68% of cohesion value, and the other 79,32% is influence by other variables.

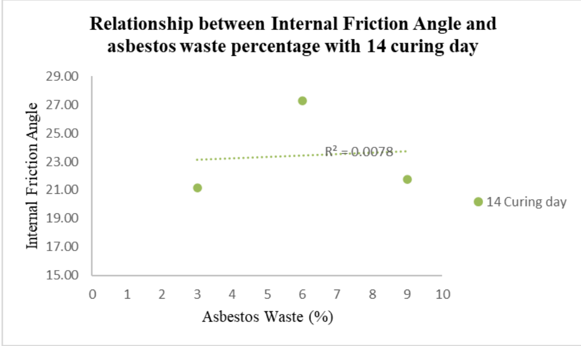

Figure 3 Relationship between Internal Friction Angle and asbestos waste percentage with 14 curing day

Based on the analysis at **Figure 11**, the R square value is 0,0078. It means the content of asbestos waste influence 0,78% of internal friction angle value, and the other 99,22% is influence by other variables.

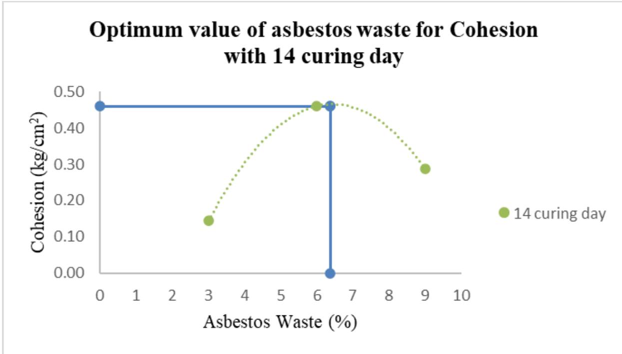

Figure 12 Optimum value of asbestos waste for Cohesion with 14 curing day

From the **Figure 12**, the graph showing the relationship between the percentage of asbestos and cohesion values with 14 days of curing, it was found that the maximum value was 0,46 with an optimum asbestos mixture composition of 6,37%.

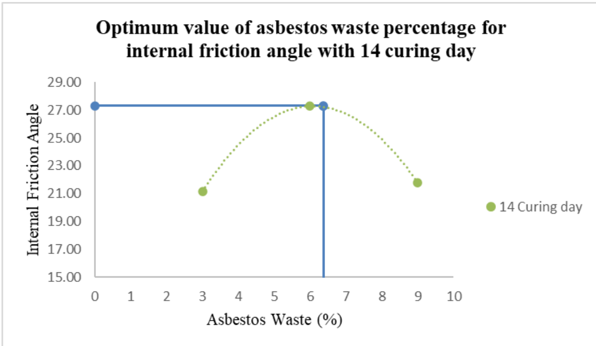

Figure 4 Optimum value of asbestos waste percentage for internal friction angle with 0 curing day

From the **Figure 13**, the graph showing the relationship between the percentage of asbestos and internal friction angle values with 14 day of curing, it was found that the maximum value was 27,3 with an optimum asbestos mixture composition of 6,37%.

Based on the figures above, it can be concluded that the maximum cohesion value after stabilization is 0,46 kg/cm², and the maximum internal friction angle of the soil is 27,3°, which occurs at the optimal composition of 6,37% asbestos waste with 14 days of curing. "The soil mixture with a 3% admixture exhibited an increase in cohesion on the first day of curing but decreased on the 14th day, whereas the 6% and 9% asbestos mixtures showed a continuous increase in cohesion over the curing period.

Building Structure

This building is constructed with a reinforced concrete structure and will be used as shoping department with beam spans of 4 meters in the x-direction and 3 meters in the y-direction, the height of every storey is 3 meter. The column dimensions are 30/30 cm, the beam dimensions in the x-direction are 25/35 cm, and in the y-direction are 20/25 cm.

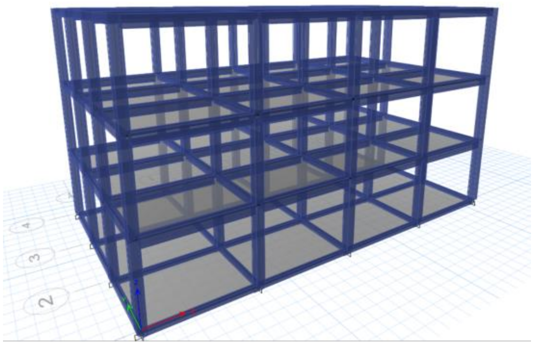

Figure 5 Modelling of Structure in ETABS

From structure model at **Figure 14**, the moment and loads that transmitted from column to foundation are:

Pu = 864,82 kN = 87,13 ton
Mu = 20,730 kN.m
My = 22,395 kN.m

The load on the foundation is obtained from the volume of the foundation plus the volume of the column in the ground, multiplied by 2400 (the density of concrete).

1. Circle = ((0,25 x 3,14 x 1,30^2) x 0,4) + (0,3 x 0,3 x 1,1)) x 2400 = 1511,83 kg = 1,51 ton
2. Square = ((1,10 x 1,10 x 0,325) + (0,3 x 0,3 x 1,1)) x 2400 = 1181,40 kg = 1,18 ton
3. Rectangle = ((1,00 x 1,50 x 0,4) + (0,3 x 0,3 x 1,1)) x 2400 = 1677,60 kg = 1,68 ton

The maximum load that can be supported by a single foundation is:

Total Load = Qv + Foundation Load
Circle total load = 88,64 ton
Square total load = 88,31 ton
Rectangle total load = 88,80 ton

Soil Bearing Capacity

To determine the capacity of soil to bear loads from the superstructure without causing failure and excessive deformation, the bearing capacity of the soil can be calculated. Calculation will be done with Terzaqhi method. For the purpose of this calculation, we make the assumption that a general shear failure will occur with a safety factor of 3. There are 3 types of foundation that used in this calculation, circle footing with Diameter = 2,45 meter; square footing with side 2,15 meter; and rectangular footing with side 2,05 x 2,20 meter.

After getting the optimum value of asbestos waste mixture which is 6,37%, the obtained cohesion (c) and angle of internal friction of the soil are 0,46 kg/cm^2 and 27,30° rounded become 27°. Based on terzaqhi bearing capacity factor for general shear failure condition, the values for Nc, Nq, and Nγ are 29,24; 15,90; and 11,60, respectively. The following is the calculation of the soil bearing capacity with the addition of 6,37% asbestos waste and 14 days of curing for several foundation variations:

1. Circle footing

   D = 130 cm; depth = 150 cm
   $c = 460$ gr/cm^2; $\phi = 27°$
   Nc = 29,24; Nq = 15,90; Nγ = 11,60
   $A = ¼ \times \pi \times D^2$
   $= ¼ \times 3,14 \times 130^2$
   $= 13.273,23$ cm^2
   $q_u = 1,3.c.N_c + \gamma.D_f.N_q + 0,6.\gamma.R.N_\gamma$
   $= 1,3.(460).(29,24) + (1,75).(150).(15,90) + 0,6.(1,75).(130/2).(11,60)$
   $= 22.445,22$ gr/cm^2

$q_{all} = \frac{qu}{FS}$
$= \frac{22.445,22}{3}$
= 7481,74 gr/cm^2
Q_{all} = q_{all} x A
= 7481,74 x 13.273,23
= 99.306.844,35 gr
= 99,31 ton

2. Square footing
S = 110 x 110 cm; depth = 150 cm;
c = 460 gr/cm^2
A = side x side
= 110 x 110
= 12.100,00 cm^2
$q_u = 1{,}3.c.N_c + \gamma.D_f.N_q + 0{,}4.\gamma.B.N_\gamma$
= 1,3.(460).(29,24) + (1,75).(150).(15,90) + 0,4.(1,75).(110).(11,60)
= 22.546,60 gr/cm^2
$q_{all} = \frac{qu}{FS}$
$= \frac{22.546,60}{3}$
= 7515,53 gr/cm^2
Q_{all} = q_{all} x A
= 7515,53 x 12.100,00
= 90.937.959,82 gr
= 90,94 ton

3. Rectangle footing
S = 100 x 150 cm; depth = 150 cm; c = 460 gr/cm^2
A = B x L
= 100 x 150
= 15.000,00 cm^2
$q_u = c.N_c.(1 + 0{,}3\ B/L) + \gamma.D_f.N_q + ½.\gamma.B.N_\gamma (1 – 0{,}2.B/L)$
= (460) . (29,24) . (1+ (0,3) (100/150)) + (1,75) . 150 . (15,90) + ½ . (1,75) . (100) . (11,60) . (1 – 0,2 . (100/150))
= 21.188,04 gr/cm^2
$q_{all} = \frac{qu}{FS}$
$= \frac{21.188,04}{3}$
= 7062,68 gr/cm^2
Q_{all} = q_{all} x A
= 7062,68 x 15.000,00
= 105.940.219,75 gr
= 105,94 ton

Based on analysis above a foundation built on soil with 6,37% asbestos waste, cured for 14 days, can safely support the planned load.

Soil Settlement

Assumed that the soil under the foundation is homogenus and only have 1 meter depth to find hard soil.

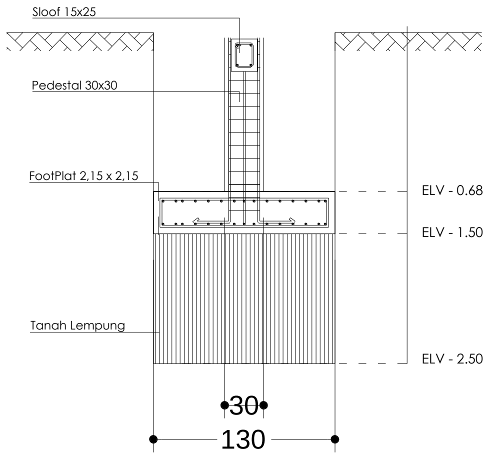

Figure 6 Soil Layer

Stabilization is carried out to a depth of 35 cm below the foundation base.

Tabel 3 Recapitulation of Soil Settlement

Type of Foundation		Original Soil	Original Soil + 3% Asbestos Waste	Original Soil + 6% Asbestos Waste	Original Soil + 9% Asbestos Waste
Circle	S_e	4,43	4,43	4,43	4,43
Footing	S_c	90,24	55,81	58,76	59,44
(mm)	S	94,67	60,24	63,19	63,87
Square	S_e	5,49	5,49	5,49	5,49
Footing	S_c	76,86	47,54	50,05	50,63
(mm)	S	82,35	53,03	55,54	56,12
Rectangular	S_e	5,32	5,32	5,32	5,32
Footing	S_c	91,56	56,62	59,62	60,31
(mm)	S	96,87	61,94	64,94	65,62

Based on **Table 3**, unsafe settlement occurred in both the natural soil and the 9% asbestos waste mixture. However, the 3% and 6% asbestos waste mixtures fell within the safe limits. Therefore, based on the previous calculations, the optimum allowable composition is 6% - 6,37%.

Implementation Method

In performing stabilization for shallow foundations using asbestos waste, excavation is carried out to a depth of the foundation plus 15 cm. Then, manual excavation is done to a depth of +35 cm, followed by manually mixing the asbestos waste with the soil.

After the soil is evenly mixed, it is then compacted using stamper to a maximum depth of 1,65 meters. If excessive compaction occurs, additional filling can be done with soil mixed with 6,37% asbestos outside the excavation. After that, the process can continue with the filling of sand backfill, the construction of the lean concrete, and then the construction of the foundation.

4. CONCLUSION

Based on the research conducted. the following are the conclusions drawn frpm this study:

1. It can be determined that the classification of the original soil using the USCS method falls into the SP-SC group. with a plasticity index (PI) 21,73%; sand percentage 94,05%; silt percentage 3,45%; and clay percentage 2,39%. In the unconsolidated undrained triaxial test. the original soil cohesion value is 0,12 kg/cm² and the internal friction angle is 11,20°.
2. The addition of asbestos waste at percentages of 3%. 6%. and 9% with curing times of 0, 1, and 14 days shows an increase in the liquid limit value and a decrease in the plasticity index. The optimum cohesion value occurs with the addition of 6,37% asbestos waste with 14 days of curing which is 0,46 kg/cm^2. The optimum internal shear angle value occurring in the 6,37% asbestos mixture with 14 days of curing which is 27,30°.
3. There is an increase in the bearing capacity of the soil between the original soil and the stabilized soil. The stabilized soil is able to effectively bear the loads transmitted by the superstructure. With the same foundation design. the original soil can only support a maximum load of 10,85 ton for a circular foundation; 9,91 ton for a square foundation; and 11,67 ton for a rectangular foundation. However. with the optimum mixture of 6,37% asbestos with 14 days of curing. the stabilized soil can support loads of 99,31 ton for a circular foundation; 90,94 ton for a square foundation; and 105,94 tons for a rectangular foundation.
4. A combined approach involving both heavy equipment and manual labor is recommended for the stabilization of shallow foundations using asbestos waste.
5. Based on cost analysis, the price for 24 points of foundation is Rp61.289.315,00- for circle footing; Rp70.608.474- for square footing; Rp65.193.793,00- for rectangle footing.

REFERENCES

[1] Asuri. S. and Keshavamurthy. P. (2016) 'Expansive Soil Characterisation : an Appraisal'. *INAE Letters*. 1(1). pp. 29–33. Available at: https://doi.org/10.1007/s41403-016-0001-9.

[2] Basack. Sudip & Purkayastha. R.. (2009). Engineering properties of marine clays from the eastern coast of India. 1.

[3] Budhu. M. (2015). SOIL MECHANICS. Wiley Blackwell.

[4] Jaya. F. A. (2010). PENGARUH PENAMBAHAN LIMBAH ASBES PADA TANAH LEMPUNG LAPINDO SEBAGAI BAHAN TIMBUNAN (Doctoral dissertation. ITN Malang).

[5] Kalantari. B. (2018) 'Foundations on Expansive Soils : A Review Foundations on Expansive Soils : A Review'. (September 2012).

[6] Panguriseng. D. (2018). Dasar-dasar Teknik Perbaikan Tanah. Yogyakarta: Pustaka AQ.

[7] Robert Kusiorowski. Barbara Lipowska. Magdalena Kujawa. Anna Gerle. (2023). Problem of asbestos-containing wastes in Poland. Cleaner Waste Systems.

[8] Roy. S. and Kumar Bhalla. S. (2017) 'Role of Geotechnical Properties of Soil on Civil Engineering Structures'. Resources and Environment. 7(4). pp. 103–109. Available at: https://doi.org/10.5923/j.re.20170704.03.