Cement Grouting Method for Increasing the Cone Value of Slopes at Semarang Multi Event Circuit, Mijen, Semarang

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Abstract. Semarang City Government is currently building sports infrastructure in the form of Multi Event Circuit. The project is located in Mijen, Semarang, Central Java. The project requires cut and fill work to fit the development plan. The first phase of construction began in early 2017, but there was a failure of slope stability due to the absence of reinforced embankment slopes. Therefore, it is necessary to stabilize the slope with geotechnical engineering. Slope improvement plan is done by grouting to increase the shear strength of the embankment. The aims of this study is to determine the increasing of cone value with cement content 5% of the total soil weight, in order to obtain the shear strength value requirement. The determination of cement content based on economical factor. Cone Penetrating Test (CPT) was performed before the grouting to determine the initial shear strength of the embankment. This test is performed in a depth of 1 m below the soil surface. Soil sampling was also conducted for laboratory tests to find the soil weight volume. The soil weight volume is required to make the remoulded soil in the vat same as the initial compacted soil. Grouting is done by pouring the cement into the 9 layers of compacted soil according to the amount of weight in the vat volume. CPT was carried out on the soil layer in the vat after 3 days to obtain the increasing of cone value. The results of these experiments will be used for design of slope stability. Based on the results of the test using the 5% cement amount of total soil weight, the average cone value increased from 7 kg/cm$^2$ to 15 kg/cm$^2$. This increasing is significant enough to improve the stability of the embankment slopes.

1. Introduction
Semarang City Government is currently building sports infrastructure in the form of Multi Event Circuit. The construction site is located in District Mijen, Semarang, Central Java. The condition of the site has an uneven topography. therefore, it must be modified to get the appropriate site plan. The project requires cut and fill worked by cutting a high plot of land and put in the low topography area. The maximum cutting height is 8 meters and maximum embankment height is 22 meters. The cutting area is relatively stable, but the embankment area need a treatment to make it stable [1,2][3].

The embankment project is not in conform with existing standard method [4], resulting in a slope failure [5–7]. The construction of the circuit line became disrupted due to the landslide, hence the work cannot be proceeded. The illustration shown in figure 1.
The project manager discusses the solution of the landslide problem with various methods proposed by the planning consultant and the construction management consultant. The proposed alternatives method is borepile, pile, anchor, terraces, and grouting. The Advantages and disadvantages of the proposed method is shown in table 1.

### Table 1. Advantages and disadvantages of the proposed method.

| Method               | Advantages                                      | Disadvantages                                                                 |
|----------------------|-------------------------------------------------|-------------------------------------------------------------------------------|
| Bore Pile            | Strength can be calculated more definitely.     | Need heavy equipment for the implementation, need access to the location so need more cost, which eventually the cost is relatively expensive. |
| Driven Pile          | Strength can be calculated more definitely.     | Need heavy equipment for the implementation, the fabrication pile is limited in length, so special connection construction is required to withstand lateral forces. Cost is relatively expensive. |
| Anchor               | Strength can be calculated more definitely.     | Embankment already exist with limited land condition, so the difficulties in the implementation. It is necessary to provide new land in front of the landslide retaining wall to start a new pile of phases so that the cost becomes more expensive. |
| Terraces             | Strength can be calculated more definitely but need to be consistent in implementation. | To obtain the form of terraces with a slope slightly, it requires extensive land acquisition. It takes time and costs are relatively expensive. |
| Combination Grouting and Retaining Wall | Technically the strength of grouting is less certain, but can be tricked with testing after the grouting. | No heavy equipment required, the implementation is relatively easy and the cost is relatively cheaper. |

From the table 1., it is proposed by using of grouting method to solve the problem of landslides that occurred in the construction of facilities and infrastructure Circuit Multi Event in Semarang. The amount of cement used is 5% of the soil weight. The choice of one cement percentage is due to time constraints.

The problem that arises is how much the soil condition will increase within the addition of 5% cement of the soil weight, and how long the cement reaction to the embankment to reach the maximum strength.

### 2. Data and method

This study was conducted by testing the soil of embankment (preliminary testing). The test is done by field test and laboratory test. This preliminary test result will be a benchmark for the value after grouting.
2.1. Grouting model
Grouting model is done by digging the soil according to the drum volume, then the drum is inserted to
the stable position (figure 2). The soil weight volume in the drum is determined, so the soil weight
volume in the drum is equal to the soil weight volume of the embankment (figure 2). Measurement the
cement by 5% of the soil weight to be inserted into the drum (figure 2). The remoulded soil is divided
into 9 parts as well as the cement is also divided into 9 parts. The first layer of soil is inserted into
the drum and then compacted. After that, the cement which has been stirred with water is also inserted
into the drum. The next layer of the cement and soil is inserted gradually as in the first part until it is
fulfilled the drum (figure 2). The model is covered that the water can not enter, resulting the natural
interaction between the soil and the cement according to the actual grouting condition, from the age of
3 days performed the model testing stage until the age of 40 days (figure 2).

![Figure 2](image)

Figure 2. Modelling process.

Soil weight, cement weight, and water weight for each drum location is shown in table 2.

| No. | Description                                      | Drum 1     | Drum 2     | Drum 3     | Unit     |
|-----|--------------------------------------------------|------------|------------|------------|----------|
| 1   | Weight of Empty Cylinder Tube                    | 0.401      | 0.401      | 0.401      | kg       |
| 2   | Volume Cylinder Tube                             | 0.000285   | 0.000285   | 0.000285   | m$^3$    |
| 3   | Weight of Original Soil                          | 0.527      | 0.525      | 0.531      | kg       |
| 4   | Weight of Cylinder Tube + Original Soil          | 0.928      | 0.926      | 0.932      | kg       |
| 5   | Volume Weight of Original Soil ($\gamma_b$)       | 1849       | 1842       | 1863       | kg/m$^3$ |
| 6   | Volume Drum                                      | 0.229      | 0.229      | 0.229      | m$^3$    |
| 7   | Weight of Soil in Drum                           | 423        | 422        | 427        | kg       |
| 8   | Weight of Cement                                 | 21.2       | 21.1       | 21.3       | kg       |
| 9   | Total Layers in Drum                             | 9          | 9          | 9          | -        |
| 10  | Weight of Soil per Layer of Filling              | 47.0       | 46.9       | 47.4       | kg       |
| 11  | Weight of Cement per Layer of Filling            | 2.35       | 2.34       | 2.37       | kg       |
| 12  | Weight of Bucket                                 | 0.35       | 0.35       | 0.35       | kg       |
| 13  | Weight of Bucket + Cement + Water                | 4.50       | 4.50       | 4.50       | kg       |
| 14  | Weight of Water per Layer of Cement Stuffing     | 1.80       | 1.81       | 1.78       | kg       |
| 15  | Percent Water Against Cement                     | 76.4       | 77.1       | 75.1       | %        |
2.2. Field test
Field testing includes Cone Penetrating Test (CPT) and sampling at all three test sites. CPT is performed on each test point of 4 stages (figure 3). Stage 1 at the original condition of embankment soil. Stage 2 on the soil in the drum that is grilled after 3 days. Stage 3 on the soil in a grouting drum after the age of 24 days. Stage 4 on the soil in a grouting drum after the age of 40 days.

The results of the CPT are shown in Table 3. Based on CPT data, we can make the average value of each point test from depth 0.2 m, 0.4 m, 0.6 m, 0.8 m, and 1.0 m. The average test is shown in table 3.

![Figure 3. CPT stages.](image)

| Depth (m) | Test Initial Conditions (0 Days) | Test-1 (Age 3 Days) | Test-2 (Age 24 Days) | Test-3 (Age 40 Days) |
|-----------|----------------------------------|--------------------|----------------------|----------------------|
| S-01-O    | kg/cm²                           | kg/cm²             | kg/cm²               | kg/cm²               |
| 0.00       | 0                                | 0                  | 0                    | 0                    |
| 0.20       | 7                                | 8                  | 6                    | 9                    |
| 0.40       | 9                                | 8                  | 5                    | 10                   |
| 0.60       | 9                                | 8                  | 7                    | 11                   |
| 0.80       | 8                                | 8                  | 5                    | 11                   |
| 1.00       | 8                                | 7                  | 6                    | 10                   |

O: Outer drum
I: Inner drum
2.3. Laboratory test
Sampling for the laboratory tests is performed on each test point of 2 stages. Stage 1, during the original condition of embankment soil. Stage 2, on the soil in a 24 days grouting in the drum. The sample of the soil from the field is an undisturbed sample (figure 4).

![Undisturbed soil sampling.](image)

Summary of the laboratory test results before grouting are presented in table 4, while the summary of laboratory test results after grouting are shown in table 5.

### Table 4. Summary of laboratory test data (before grouting)

| No. | Description      | Notation (Unit) | Test Results   |
|-----|------------------|-----------------|----------------|
| 1   | Sample Name      | -               | Test-01 Test-02 Test-03 |
| 2   | Sample Condition | -               | UD UD UD       |
| 3   | Depth            | D (m)           | 0.00-0.40 0.00-0.40 0.00-0.40 |
| 4   | Bulk Density     | $\gamma_b$ (gr/cm$^3$) | 1.802 1.798 1.698 |
| 5   | Moisture Content | w (%)           | 39.503 40.227 44.697 |
| 6   | Dry Density      | $\gamma_d$ (gr/cm$^3$) | 1.292 1.282 1.173 |
| 7   | Specific Gravity | GS              | 2.694 2.665 2.644 |
| 8   | Void Ratio       | e               | 1.086 1.078 1.253 |
| 9   | Strength parameter: | | |
|     | - Direct Shear   | $\phi$ ( ° )    | 30.10 25.99 27.76 |
|     |                 | e (kg/cm$^3$)   | 0.654 0.586 0.467 |

UD: Undisturbed

### Table 5. Summary of laboratory test data (after grouting)

| No. | Description      | Notation (Unit) | Test Results   |
|-----|------------------|-----------------|----------------|
| 1   | Sample Name      | -               | Test-01 Test-02 Test-03 |
| 2   | Sample Condition | -               | UD UD UD       |
| 3   | Depth            | D (m)           | 0.00-0.40 0.00-0.40 0.00-0.40 |
| 4   | Bulk Density     | $\gamma_b$ (gr/cm$^3$) | 1.790 1.776 1.702 |
| 5   | Moisture Content | w (%)           | 40.187 42.079 45.067 |
| 6   | Dry Density      | $\gamma_d$ (gr/cm$^3$) | 1.277 1.250 1.173 |
| 7   | Specific Gravity | GS              | 2.687 2.672 2.665 |
| 8   | Void Ratio       | e               | 1.104 1.138 1.271 |
| 9   | Strength parameter: | | |
|     | a. Direct Shear  | $\phi$ ( ° )    | 18.00 15.97 17.88 |
|     |                 | e (kg/cm$^3$)   | 0.696 0.696 0.654 |

UD: Undisturbed
3. Result and discussion

The average data value of the conus (kg/cm²) with the test time (days) is shown in Table 6. From the average value of Table 6, it can be drawn graph of the relationship between time and value of conus of each test point. The conus value relation (kg/cm²) within the test time (day) is shown in Figure 5.

| Test Initial Conditions (0 Days) | Test-1 (Age 3 Days) | Test-2 (Age 24 Days) | Test-3 (Age 40 Days) |
|---------------------------------|---------------------|----------------------|---------------------|
| S-01- O                        | S-02- O             | S-03- O             | S-01- O            |
| S-01- I                        | S-02- I             | S-03- I             | S-01- I            |
| S-01- I                        | S-02- I             | S-03- I             | S-01- I            |

Average 8.2 7.8 5.8 10.8 9.2 24.0 19.4 18.8 21.6 21.6 19.6

O: Outer drum
I: Inner drum

Based on Figure 5, the average conus resistance analysis of each test point is performed. The average data indicate that there are significant increasement of conus value from 3 days until 24 days. The increasement shown that there is a maximal interaction of cement retention to the remoulded soil, therefore it can be seen that there is optimum pavement for 21 days. The conus value increasement does not occurred significantly even tends to be stable at 24 days to 40 days. It can be concluded that the interaction of cement and soil has stabilized (no increase) after 24 days.

![Figure 5](image)

**Figure 5.** Relation chart of conus value and time of testing.

From the laboratory test results of both conditions in Table 4 can be summarized value of shear strength parameters. The cohesion (c) and friction angle (\(\phi\)) before and after grouting, and the average values of all three test points are shown in Table 7.

| Test Point | Value \(\phi\) Before \(^{\circ}\) | Value \(\phi\) After \(^{\circ}\) | Value c Before (kg/cm\(^2\)) | Value c After (kg/cm\(^2\)) |
|------------|-------------------------------|-----------------------------|-----------------------------|-----------------------------|
| 01         | 18.00                         | 30.10                       | 0.696                       | 0.654                       |
| 02         | 15.97                         | 26.99                       | 0.696                       | 0.586                       |
| 03         | 17.88                         | 27.76                       | 0.654                       | 0.467                       |
| Average    | 17.28                         | 28.28                       | 0.682                       | 0.569                       |
Based on table 7 above, it can be concluded that before and after grouting, there is a significant increasing of friction angle parameters and a slight decreasing of the cohesion values.

4. Conclusions
Based on the study that has been done. It can be concluded as follows. The addition of cement paste into the soil layer with the percentage of cement 5% of the soil weight, there is an increasing of conus value from 0 days (7 kg/cm$^2$) to days of 24 (21 kg/cm$^2$). There is an increasing of soil shear strength from the age of 0 days by 17.28° to 28.28° at days of 24. There is a decreasing in cohesion value from 0.682 kg/cm$^2$ at 0 days to 0.569 kg/cm$^2$ at days of 24.

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