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SLOPE IMPROVEMENT IN THE HIGH LANDFILL BY GROUTING CEMENT (GE)

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Abstract

To build a building on a hilly area have to be started with properly soil investigation and properly geodetically survey. Ignored those investigation and survey will hurt, the building can collapse or land sliding can occur. The incident of high landfill sliding occurs in a building construction located in Tembalang Semarang. The building was constructed over the more than seven meters height of landfillwith very steep of slope horizontal to vertical was 1 : 4 without preceded with properly soil investigation and geodetically survey. This paper reported that incident and come up with the cause of slope sliding and analyzed as well as the effort to solve it. In the analysis was found out about that the landfill was constructed without preceded with properly planning and design which conducted based on the data of soil investigation and geodetically survey. From the analysis were known that slope sliding because of landfill constructed in dry season where void in the soil was 0% of water fully filled with air. When heavy and long rain was fall, the void filled with water, unit weight of soil increase and because of weight of building construction over the landfill, and because of the steep of slope, landsliding cannot be avoided. To solve that problem, grouting technique using cement was performed. The result show satisfied that the sliding can be stopped.

Keywords: Landfill, Steep slope, Land- Sliding, Soil investigation, Cement-Grouting,

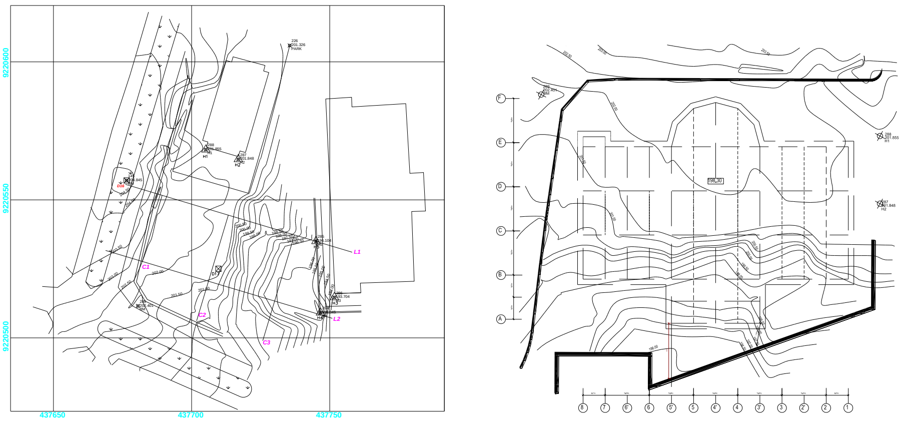
Introduction

This paper analyzes land sliding in the high landfill slope in the building located in Tembalang – Semarang. Varies of elevation of the land surface require cut and fill of land to get flat surface for building. Because of inaccuracy in geodetic survey, high landfill has to be constructed to adjust the fixed elevation. Those high landfill with the proper and save of slope has not prepared yet in the design. As the result, the high elevation of slope can reach 7 meters as shown in contour map in Figure 1.

Building is planned have a three story using pile foundation, however, design of retaining wall just prepared within construction after requires high landfill is detected. The front side of the building sited at higher elevation than the back side, and most of the first floor sited in the fill area. The soil materials for fill are taken from cutting the land in front of the building. The properties of the landfill is shown in Table 1 and Table 2, the property of soil for fill and shear strength of the fill material respectively, and categorized as good materials for fill construction.

Problems statement

The sequence of the construction, first is driven pile foundation, construction of pile cap, foundation beam, and followed by leveling the ground (without properly compaction) just use to stand of scaffolding for second floor construction. After construction of second floor completed, leveling of ground in the first floor is continued until reach the require elevation and compacted.



(a) **(b)**

Figure 1: Contour map in the discus location

Table 1 Property of soil for fill material

Sample Code	Depth (m)	Water Content (w) %	Spesific Gravity of Solid	Unit weight γ (gr/cm^3)	Dry unit weight γ_d (gr/cm^3)	Porosity (n)	Void Ratio (e)
1	-01.00	36.2	2.6914	1.6712	1.2270	54.41	1.1934
2	-02.00	33.45	2.6851	1.6655	1.2480	53.52	1.1515
3	-03.00	31.86	2.6840	1.6668	1.2641	52.90	1.1233
4	-04.00	30.01	2.6928	1.6718	1.2859	52.25	1.0941

Table 2 Shear strength parameter of the fill material

Sample Code	Depth (m)	C (kg/cm^2)	ϕ (°)
1	-01.00	-	-
2	-02.00	-	-
3	-03.00	0.14	19
4	-04.00	0.13	21

As mentioned above, the the landfill construction have not planed beforehand and not include in the schedule, therefore, the ground can not be properly compacted. In addition, the slope is very high and too steep with ratio of horizontal to vertical is 1 : 4. Fill construction is also constructed in the dry season, and this can be put in the risk of slope since lack of water content as shown in Figure 2a.

The other shortage of the landfill work that comes along during construction is that the soil works still lasted when finishing work, the retaining wall, as well as septic tank work has started, as shown in the Figure 2b.

(a) (b)

Figure 2: Landfill construction

When heavy rain falls in the long time, land sliding occurs. Effect of the land sliding is occurrence the significant deformation on the foundation of the stairs structure, and differential settlement in the first floor construction.

Figure 3 shows model of fill and slope in land sliding analysis using Plaxis 7.2. programme. Upper part with dark grey is landfill and the bottom layer is the native soil.

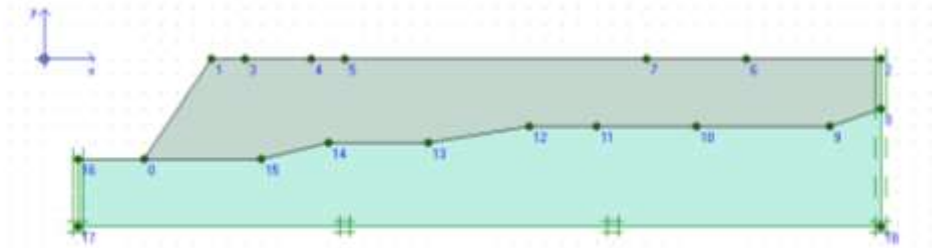


Figure 3: Plaxis 7.2 model for fill and slope (Arief, 2008)

When dry and rain is not fall, slope is saved and there is no sliding occurs. Maximum strain in the fill only 0.52% show in the Figure 4.

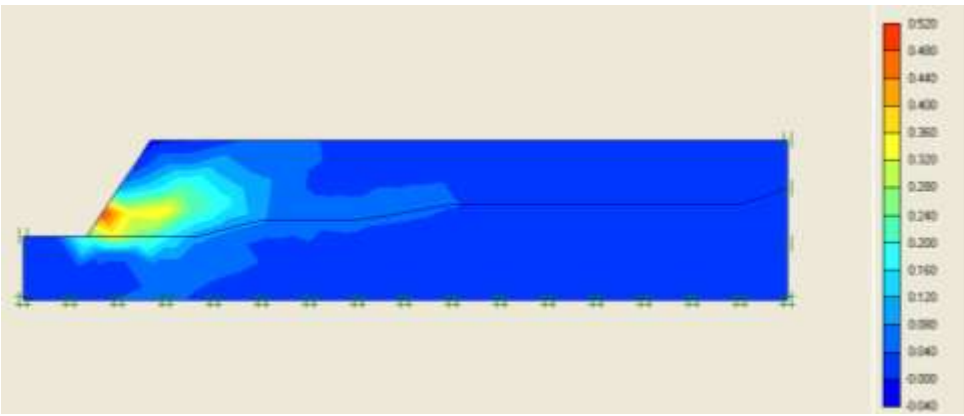


Figure 4: Strain in the slope when soils dry (Arief, 2008)

When heavy and long rain is fall, the over flow of water form front side will flow to the low part to the landfill in the building cause the water level position raise as shown in Figure 5.

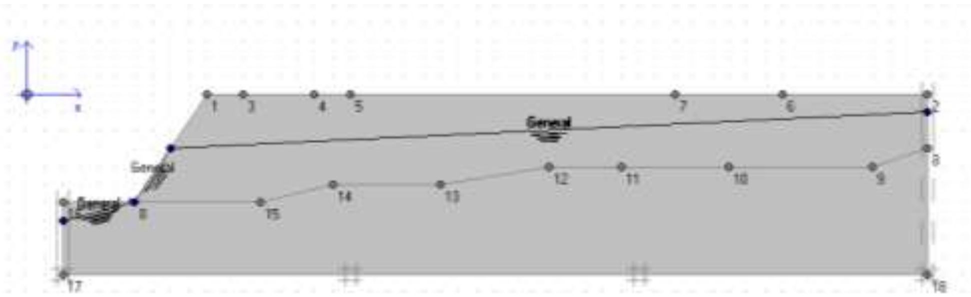


Figure 5. Water level when heavy rain (Arief, 2008)

When the water level is raise, the soil under the ground water level will highest. This condition makes the stress to the slope increase and the shear strength decrease. Figure 6 shows the mechanism of sliding occurs when the slope is collapse. From that figure show that sliding occurs at the side of the slope, and increasing of strain reach 1.1%.

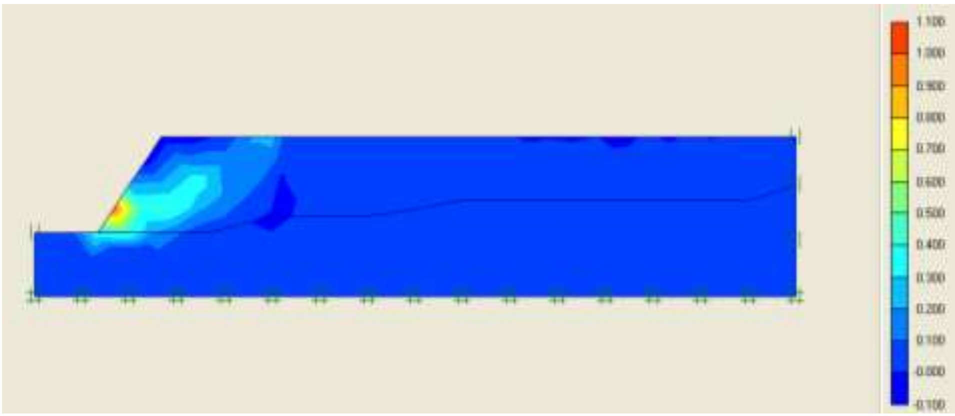


Figure 6. Incremental strain when there was heavy rain (Arief, 2008)

Methods of Slope Stabilization

There are five methods of slope stabilization, unloading, drainage, Buttressing, Reinforcement, and retaining wall(Abramson et al., 1995)

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1) Unloading

Unloading is a technique to reduce the driving force within a slide mass. The most common type of unloading is excavation of the head of a slide (Figure 7). Excavation is a common method for increasing the stability of a slope by reducing the driving forces that contribute to movements. Unloading can include : removing weight from the upper part of the slope, removing all ubstable or potentially unstable materials, flattering slopes, and benching. In the case where the construction of a conventional embankment can lead to slope instability, lightweight fill materials can be used to lessen the driving forces caused by the embankment. In embankment construction lightweight fill can reduce the driving force of the slope and thereby increase the stability. Lightweight materials, such as slag, encapsuled sawdust, expanded shale, cinders, shredded rubber tires, polystyrene foam, and sea shells, have been used successfully. Selection of the type of lightweight material depends on its cost and availability in local areas

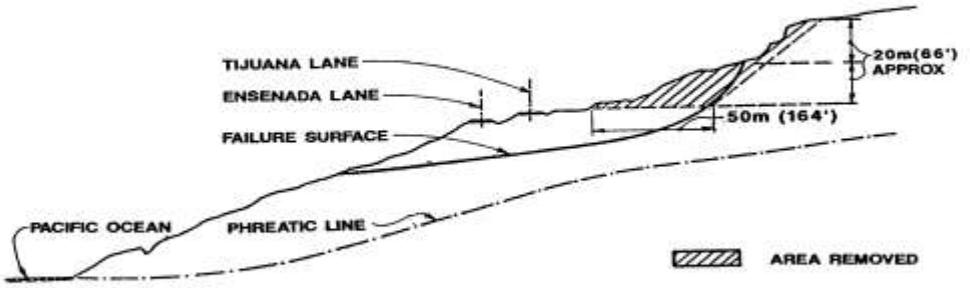

Figure 7. Removal of landslide head (Rodriguez et al.)

2) Drainage

Of all stabilization technique considered for the correction or prevention of landslides, proper water drainage is the most important. Drainage reduces the destabilizing hydrostatic and seepage forces on slope as well as the risk of erosion and piping. Unloading can include surface drainage, sub surface drainage (Figure 8)

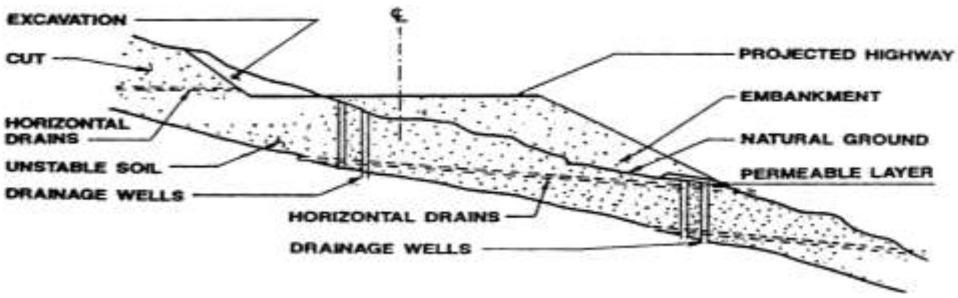

Figure 8 Drainage well combined with horizontal drain (Rodriguez et al.)

3) Buttressing

Buttressing is a technique used to offset or counter the driving forces of a slope by an externally applied force system that increases the resisting force. Buttresses may consist of soil and rock fill, counterberms, shear keys, mechanically stabilized embankments.

Soil and rock fill is used to provide sufficient dead weight near toe of unstable slope to prevent movement. Where resources are available and where soil and rock fill can be found locally, this methode is the most practical way to arrest further movement of an unstable slope.

A counterberm is used to provide weight at toe of a slope and increase the shear strength below thw toe. This is particularly useful for embankments over soft soil where the ground at toe can move upward and form a bulge (Figure 9). By locating a counterberm where the upheaval is expected to occur, the resisting against sliding is also increased.

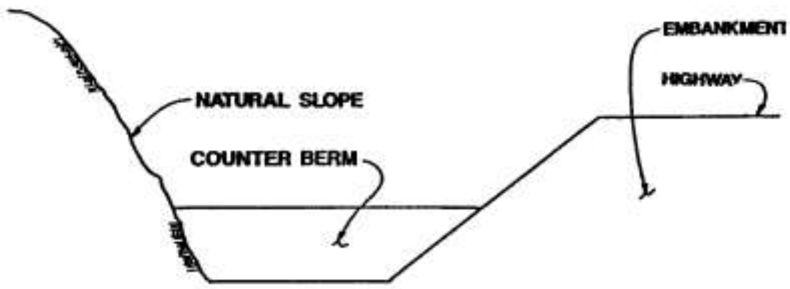

Figure 9 Counterberm to provide weight at toe of embankment (Abramsonet al.)

Shear keys are used sometimes to provide additional sliding resistance for a counterberm or rocky/soil buttress. The main purpose of a shear is to force the critical slip circle deeper into a stronger underlying formation, thereby increasing the resistance along the slip surface. This method becomes very practical and cost effective if the stronger formation is only a few feet below the overlying soft soils.

Machanically stabilized embankments (MSE) involve the designed use of backfill soil and thin metallic strips, mesh, or geosyntetic reinforcement mesh to form a gravity mass capable of supporting or restraining large imposed loads. The MSE slope face is either vertical or inclined, and the backfill material is typically confined behind metal, reinforced concrete, or shotcrete facing.

4) Reinforcement

Reinforcement may consist of soil nailing, stone columns, reticulated micropiles, geosynthetic reinforcement slopes.

Soil nailing is a method of in situ reinforcement utilizing passive inclusions that will be mobilized if movement occur, It can be used to retain excavations and stabilize slopes by creating in situ, reinforced, soil retaining structures. The main application are shown schematically in Figure 10. In soil nailed excavation, the reinforcement generally consits of steel bars, metal tubes, or other metal rods that resist tensile stresses, shear stresses, and bending moments imposed by slope movements.

Stone columns can be used to stabilize or prevent landslides. This ground inprovement technique increases the average shear resistance of the soil along potential slip surface by replacing or displacing the in situ soil with a series of closely spaced, large diameter columns of compacted stone. In addition, stone columns also function as effecient gravel drains by ptoviding a path for relief of pore water pressure, thereby increasing the strength of the sorrounding clayley soil.

Raticulated micropiles were developed in Italy and are used to create a monolitic rigid block of reinforced soil to a depth below the critical failure surface. The piles used in this way are similiar to soil nailing systems.

Geosystetic soil reinforcement is another technique used to stabilize slopes, particulary after afailure has occured or if a steeper than safe unreinforcement slope is desirable. In addition, it can improve on the edge of a slope, thus decreasing the tendency for surface sloughing (Figure 11).

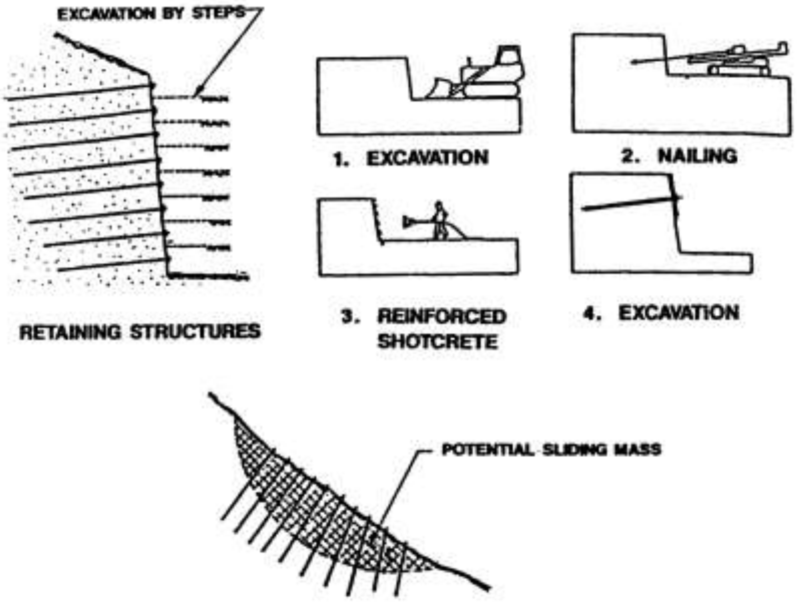

Figure 10 main application of soil nailing (Mitchell and Villet)

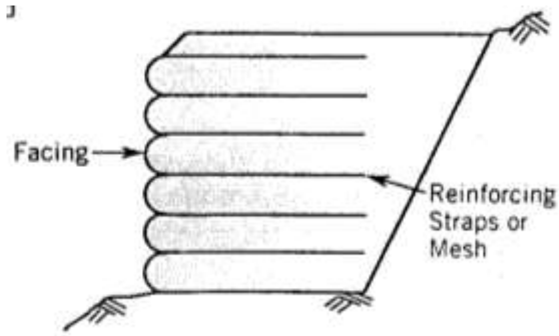

Figure 11. Schematic diagram of a reinforced soil using geosynthetics (Mitchell and Villet)

5) Retaining walls

The most common use of retaining walls for slope stabilization is when a cut or fill is requaired and there is not sufficient space or right of way available for just slope itself. The wall should be deep enough so that the critical slip surface passes around it with the adequate FOS as shown in Figure 12. In addition, the ability of retaining wall to perform as a stabilizing mass is a function of how well it will resist overturning moments, sliding forces at or below its base, and internal shear forces and bending stresses. Retaining wall types include conventional gravity or cantilever retaining walls, driven piles, drilled shaft walls, and tieback walls. Each of these retention systems is discussed in the following subsections. Since it considerably difficult and costly for the retention system to block ground water flow, walls should be designed with adequate drainage systems behind or through the walls

Those methods could not be used to overcome sliding embankment in Tembalang because its construction needed long time to build and needed heavy equipment.

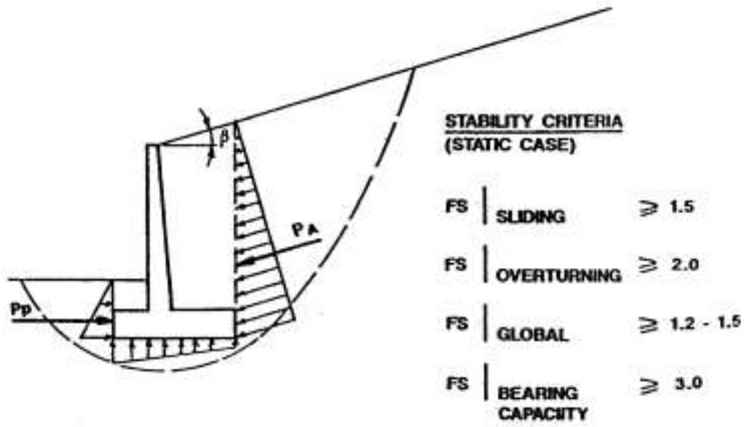

Figure 12 Different wall stability criteria (static case) (Abramson et al.)

Slope strengthen using grouting cement

Grouting technique can be classified into four groups include permeation grouting, compaction grouting, hydro-fracturing grouting, and jet grouting. (Liong G. T, 2006)

1) Permeation grouting

In permeation grouting (Figure 13a) low viscosity of grout material injected to the ground using relatively low pressure and stress. The relatively low of pressure and stress is intended to minimize the disturbance to the structure as small as possible. In this technique, the material for grout flow through the pore of the soil. This technique is suitable for soil which has permeability less than 10^{-5} m/second, like sandy soil.

2) Compaction grouting

Figure 13b shows the compaction grouting technique. This technique use high viscosity material and injected using relatively high of pressure and stress. By using relatively high pressure and stress, the material remain all in one piece and can be stressed the soil surround the location of injection. Stress will push and compacted the soil surround it. Compaction grout technique use for low permeable soil like clay.

3) Hydro-fracturing grout

In hydro-fracture grouting (Figure 13c) grout material injected by using higher stress and soil tensile strength such a way the soil will crack and the material will infiltrate into in, and become solid in the voids of the soil. This technique is suitable for clay and sandy soil, however difficult to control and have risk to disturb the soil surround it.

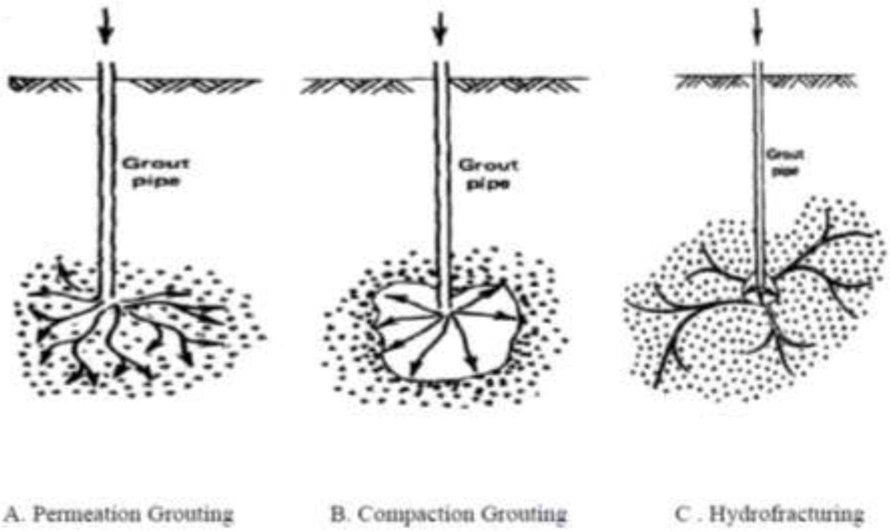

Figure 13. Types of grouting system (Liong. G. T, 2006)

4) Jet grouting

In this technique, grouting materials are injected into soil by using jetting technique pressure between 100 – 800 kg per square meter. This technique includes fracturing and mixing the existing soil with grout material. If necessary soil can be pushed out and changed partly or fully with grouting material. By this way, cement columns with high shear or compressive strength will form.

In case of land sliding of high landfill in Tembalang area, permeation grout is used to solve it since the soil use for fill is granular material with high permeability.

Process of grouting is conducted in the sliding area where the sliding have caused deformation in the foundation.

Equipment's use in cement grouting among other thing is silo, mixer, 800 kg per square meter of high pressure pump, compressor with capacity 2400 liter per minute and pressure 12 kg per cubic centimeter, hydraulic plastic pipe, drilling machine, and swivel.

The process conducted includes ground drilling by penetrating of drilling pipe to the planed deep 2, 3, and 5 meters. After reaching the required deep, water cement then take it out from the grout pipe. In grouting cement, cement can spread widely by lower pressure. 40 bag of cement content 40 kg each bag use up but there are no indication that whole void in the soil have filled with cement.

Even though increasing of shear strength in the cement grouting cannot be properlymeasured, but cement grout is effective enough to solve the sliding problem. There are no more slope sliding in the same or in other location after grouting is conducted.

Conclusion

From the discussion above, can be drawn the conclusions as follows:

1. Building located in the hilly area must be thoroughly and properly planed and design.
2. Geotechnical and geodetic survey must be carefully conducted, both in the location of building and quarry.

3. By doing properly survey, foundation and other structure can be planned and designed without any mistaken.
4. The properties of soil and volume of soil resulted from properly survey in the quarry is valuable for designing the high landfill.
5. Cement grouting can be considered to use in designing of slope of landfill if the cement can mixed with soil and can improve the shear strength.

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