Slope reinforcement using HDPE uniaxial geogrid

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ABSTRACT: This paper will discuss about slope reinforcement by using geosynthetics of HDPE Uniaxial Geogrid. The slope reinforcement shall be used in order to optimize land use of a residential houses at South Tangerang, Indonesia. Right in front of the slope, there is a river bank which flood during rainy seasons. To optimize the land use as residential areas, the surface elevation must be above the flood water level, hence a 15 meters of embankment need to be constructed. To reach the embankment design height, a HDPE Uniaxial Geogrid material (geosynthetics) was chosen as reinforcement material to stabilize the slope. A geotechnical software, ReSSA (Reinforced and Unreinforced Slope Stability Analysis) 3.0, were used for slope stability analysis. The available fill material at site was red soil which is a cohesive soil type. Therefore, it requires a good drainage system so the developed pore water pressure can be dissipated through the drainage layer. A uniform grade of crushed stones (granular) was used as drainage layer. The combination of granular material and cohesive soils on geogrids has shown good stability in reinforcing the slope.

Keywords: *slope reinforcement, geogrids, slope failure, landslides*

1 INTRODUCTION

A residential project development were planned in an area along the riverbank of Cisadane River in Serpong, South Tangerang. A residential area commonly shall not be located at riverbank due to flood threat. Thus the area along the river can not be developed and utilized. To optimize land utilization, the developer decided to elevate the area about 15 m higher from the river bank area, thus the elevated area will be free from flood and can be utilized. It had been a slope failure when 15 m elevated area constructed without reinforcement which can be seen in Figure 1. Geosynthetics was introduced to reinforce the 15 m slope to provide a stable slope. Type of the geosynthetics used for this case is HPDE uniaxial geogrid with wrap around as facing type.

Figure 1: Embankment Slope Existing Condition before Slope Reinforcement Construction

2 GEOSYNTHETICS

Etymologically, geosynthetics derived from geo which means earth and synthetics which means human made products. Generally, geosynthetics are polymer products that used to reinforced earth, or other geotechnical material that is part of man-made structures.

There are many types of geosynthetics, for example: Geotextile, Geogrid, Geonet, Geomembrane, Geosynthetic Clay Liner, Geofoam, Geocell, Geocomposite

Each type of geosynthetics has its own characteristic and function which can be summarized in Table 1 :

Tabel 1 Geosynthetic Function

Type	Separation	reinforcement	Filtration	Drainage	Barrier
Geotextile	√	√	√	√	
Geogrid		√			
Geonet				√	
Geomembrane					√
GCL					√
Geofoam	√				
Geocell	√	√			
Geocomposite	√	√	√	√	√

Type of geosynthetics that usually used for slope reinforcement is geotextile and geogrid. For reinforcement case, geogrid has an advantage, which is smaller elongation compared to geotextile. Generally geogrid can be divided into uniaxial geogrid and biaxial geogrid, uniaxial geogrid is georid that can bear tensile load in one direction only, which is parallel to length of roll. Biaxial geogrid is geogrid that can bear tensile load in two direction, parallel and perpendicular to roll length. For slope case, the dominant loading is just one direction, which is parallel to the slope direction, so uniaxial geogrid is more suitable for slope stability case.

According to Mitchell and Villet (1987), in a soil reinforcement system, combination between soil and reinforcement should produce composite material that has better strength. Usually soil is strong in compression, but weak in tensile, and can be reinforced by tensile reinforcement.

Cooperation between soil and reinforcement result in better material strength, because there is loading transfer between soil and reinforcement.

Mitchell and Villet (1987) divide reinforcement type into two, extensible reinforcement and inextensible reinforcement. Generally, almost all of soil reinforcement is inextensible, except geosynthetics. Because geosynthetics has much higher elasticity modulus than soil, geosynthetics can resist soil deformation parallel to the reinforcement. So, the reinforcement is considered increase soil cohesion or increase confining pressure.

Geosynthetics allowable strength for designing purpose is ultimate strength divided by appropriate reduction factor based on several condition. To calculate allowable strength, the following formula can be used:

$$\sigma_{all} = \sigma_{c}.\ [1/f_{CR} \times 1/f_{D} \times 1/f_{ID} \times 1/f_{UNC}]$$

Where σ_{all} is allowable geosynthetics strength, σ_c is ultimate geosynthetics strength, f_{CR} is creep reduction factor, f_D is environment reduction factor, f_{ID} is installation damage reduction factor, and f_{UNC} is uncertainty reduction factor. Geosynthetics selection is depends on two factor, internal factor and external factor.

The internal factor consisted of geotextile tensile strength, creep, geotextile structure, and environment durability, and the external factor is type of soil that interact with the geotextile. Geosynthetics structure is also take part in determination of geosynthetics type. Environmental factor also take part in reducing the geotextile strength, ultraviolet, marine environment, pH, and microorganism can reduce the geotextile strength. Loading duration can also reduce geotextile strength because degradation occur over time. To overcome that, allowable strength is used in designing geosynthetics structure instead of ultimate strength.

3 SLOPE REINFORCEMENT DESIGN

Slope reinforcement in this case is an earth retaining wall which is consist of reinforced backfill with HDPE uniaxial geogrid reinforcement, wrap in facing type. In the inner side of the facing, soil bag was placed to prevent backfill loss through the facing. After some time, the soil bag will decay and promote vegetation grow at the facing.

Slope reinforcement was designed with geotechnical software ReSSA (3.0) with the following inputs (see Table 2) :

Tabel 2 Soil Parameter for Analysis

Input	Timbunan I	Timbunan II	Tanah Asli I	Tanah Asli II	Split
γ (kN/m^3)	16,8	16,1	20	16,5	20
c (kN/m^2)	32	0	0	15	0
φ (°)	18,3	20,6	50	19	26

System geometry input for ReSSA (3.0) can be seen on Figure 2. Surcharge 5 kPa simulate light road loading, and surcharge 15 kPa simulate houses loading.

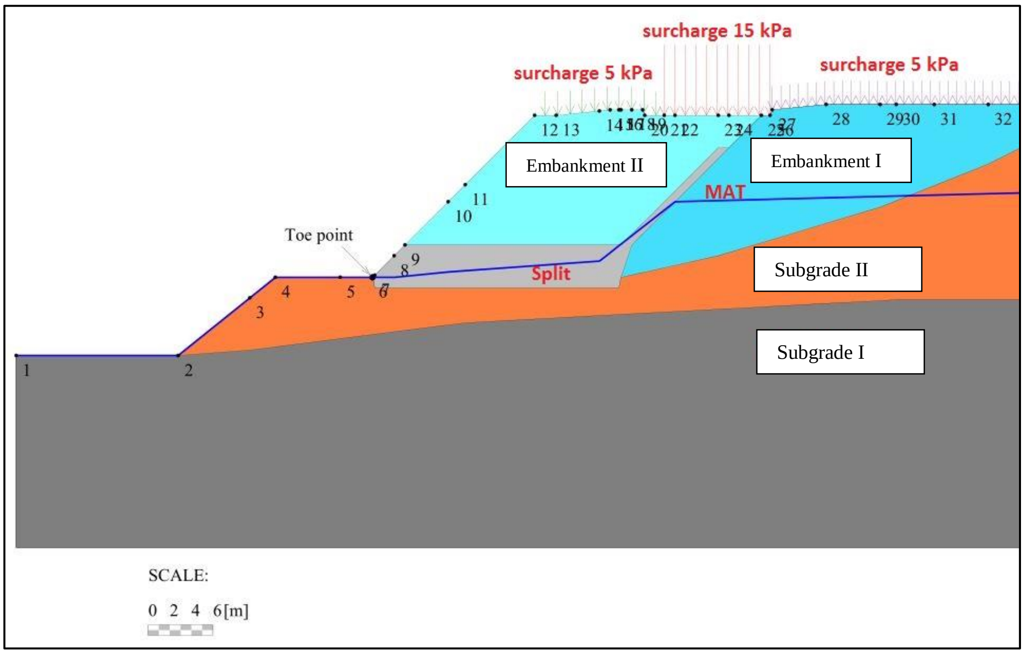

Figure 2: Slope Reinforcement Typical System Geometry on ReSSA (3.0)

Subgrade is divided into two, Subgrade I, and Subgrade II. Subgrade I is a dense and hard subgrade, and Subgrade II is a softer subgrade. Embankment is also divided into two, Embankment I , and Embankment II. Embankment I is the first embankment built before slope reinforcement is constructed. The Embankment I is not stable and landslide always occur. Due to the landslide, slope reinforcement is introduced as a solution. There is a drainage layer, to dissipate the developed pore water pressure inside the embankment. There are two types of HDPE Uniaxial Geogrid used: UX TERRA GRID 120, and UX TERRA GRID 90, with the following specification (see Table 3):

Tabel 3 Geogrid Specification

Parameter	UX TG 90	UX TG 120
T_{ult} (kN/m)	90	120
RF_{id}	1,1	1,1
RF_d	1,1	1,1
RF_c	1,1	1,1
RF_a	1	1
R_c	1	1
Cds-phi	0,6	0,6
Cds-c	0	0
Ci	0,8	0,8
Alpha	0,8	0,8

Note:
Tult (kN/m) = Ultimate tensile strength
RF_{id} = Reduction factor for installation damage
RF_d = Reduction factor for durability
RF_c = Reduction factor for creep
RF_a = Additional reduction factor
R_c = Coverage ratio
Cds-phi = Direct sliding interaction parameter
Cds-c = Direct sliding interaction parameter
Ci = Pullout interaction parameter
Alpha = Pullout interaction parameter

Here is summary of geogrid reinforcement used (see Table 4):

Tabel 4 Geogrid Height and Length

No.	Type	Height from Toe (m)	Length (m)
1	UX TG 120	0	20
2	UX TG 120	0,5	20
3	UX TG 120	1	20
4	UX TG 120	1,4	20
5	UX TG 120	1,8	20
6	UX TG 120	2,2	20
7	UX TG 120	2,6	20
8	UX TG 120	3	20
9	UX TG 120	3,4	20
10	UX TG 120	3,8	20
11	UX TG 120	4,2	20
12	UX TG 120	4,6	20
13	UX TG 120	5	20
14	UX TG 120	5,4	20
15	UX TG 120	6	20
16	UX TG 120	6,6	20
17	UX TG 120	7,2	20
18	UX TG 120	7,6	20
19	UX TG 90	8,2	20
20	UX TG 90	9,2	20
21	UX TG 90	10,2	20
22	UX TG 90	11,2	20
23	UX TG 90	12,2	21
24	UX TG 90	13,2	21
25	UX TG 90	14,2	21

ReSSA (3.0) can calculate slope stability with three different method, which is Bishop, Spencer (2-part wedge), and three part wedge. It can be seen on Figure 3 each slip circle for those three method.

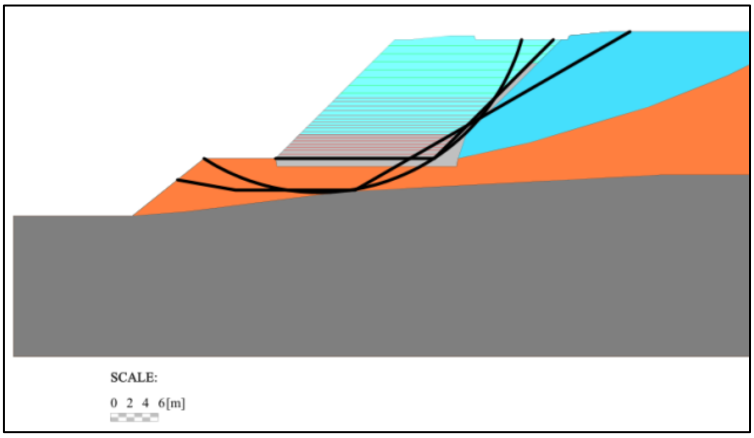

Figure 3: System Geometry with three slip circle on ReSSA (3.0) output

Safety factor for each method can be seen on the following table (see Table 5):

Tabel 5 Safety Factor from Analysis

Method	SF
Bishop	1,25
Spencer	1,27
Three-Part Wedge	1,6

Based on Sowers (1979), safety factor higher than 1,2 can be considered safe, and based on Bowles (1989), safety factor higher than 1,25 can be considered stable.

Slope Reinforcement Construction Process can be seen in Figure 4,5,6, and 7

Figure 4: Slope Reinforcement Construction Process (1)

Figure 5: Slope Reinforcement Construction Process (2)

Figure 6: Slope Reinforcement Construction Process (3)

Figure 7: Slope Condition after Construction

4 CONCLUSION

A slope consist of cohesive soil can be reinforced by using HDPE Uniaxial Geogrid. Slope with 15 m of height was reinforced using 20 m length of HDPE Uniaxial Geogrid. The geogrid was placed with spacing 0.4 m for Geogrid with tensile strength of 120 kN/m, and for Geogrid 90 kN/m, the spacing is 1 m. As a result, this configuration generate a safety factor value more than 1.25. To date (after 3 years) the slope reinforcement shows good stability and performances. The front facing is fully covered with vegetation, as can been see in Figure 9.

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This paper represent a case study conducted by author when involving in design and construction process from commencement of the projects until completion.

REFERENCES

Sowers, G. F. (1979). “Introductory Soil Mechanics and Foundations”. Macmillan: New York.
Bishop A. W. (1955), “The use of the slip circle in stability analysis of slopes,” Geotechnique 5.
Spencer, A. (1967), “A method of analysis for stability of embankments using parallel inter-slice forces,” Geotechnique 17.