Geosynthetic reinforced earth system design under earthquake-prone area study case : Jakarta and West Sumatera

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ABSTRACT: The application of geosynthetic materials have become one of alternative solution for earth retaining structure. The materials like woven geotextiles and geogrid are combined into one retaining structure system. The geogrid plays as reinforced element and the non-woven plays as separator between the fill material and the existing soil. The geogird are anchored into the compacted soil to create the elements bonding. The length of geosynthetic materials that is anchored in the soil have approximately 0,7 of the height of the retaining structure. On the other hand, in the area which is prone to earthquake like Indonesia which has various value of ground acceleration. The study case is taken from the project experience in Jakarta and West Sumatera where the PGA values are 0,4g and 0,6g. From this value of PGA, the formula of geogrid anchorage 0,7 by the wall height is not sufficient. The variation of peak ground acceleration (PGA) value gives high influence by the change of active pressure coefficient K_{AE} value. The change of active pressure coefficient is increase the length of geosynthetic materials anchorage.

Keywords: anchorage, compaction, earthquake, geogrid,

1 INTRODUCTION

Application of geosynthetic for earth retaining structure is widely used and become as an alternative design of concrete retaining wall structure. The design of geosynthetic reinforced earth system is based on two main factor, there are the wall height and the compaction of the soil. The wall height gives the preliminary prediction of geogrid anchorage, and the soil compaction of the backfill material in the field is to control the in situ density of the soil. Both of the factors must also consider the earthquake loading that may occur without prediction. The calculation of the earthquake loading to the retaining wall must be done based on the location. Indonesia is one country that is prone to earthquake with various peak ground acceleration based on the earthquake zone map of Indonesia.

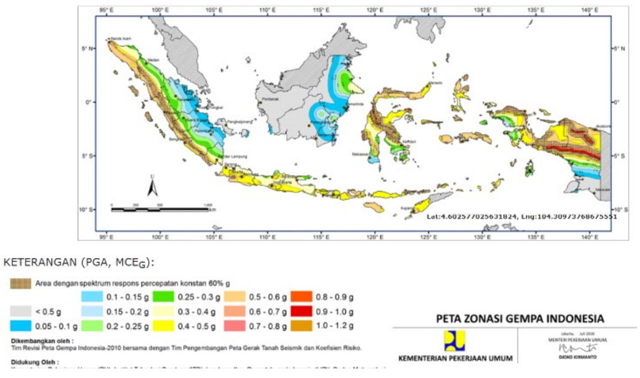


Figure 1. Indonesia Earthquake Zone Map

A high value of PGA shows that the earthquake is strong that may cause failure in the retaining structure. The calculation must consider the global rotational sliding and the direct sliding of the structure. In this paper, the study case is taken from the west Sumatera and Jakarta area based on the experience of slope remediation and slope reinforcement using geosynthetic materials. From the map above, the PGA value of West Sumatera is 0,5g and the Jakarta is 0,36g. The design of the retaining wall is using local soil that exist in the area. In general, the best material for backfill is granular material because the mechanical properties are better than fine grained material. On the other hand, the granular soil sometimes is not available due to the price and the location, hence the local soil is selected and used as backfill material.

2 LITERATURE

2.1 *Soil backfill*

The soil backfill material must be compacted minimum 95% of dry weight laboratory. The recommendation of backfill material is on the table below (Koerner, 2005).

Table 1. Recommendation of soil gradation for backfill

Sieve Size (No.)	Particle Size (mm)	Percent Passing
4	4.76	100
10	2.0	90-100
40	0.42	0-60
100	0.15	0-5
200	0.074	0

From the table above, the recommended materials for backfill is Gravel-Sand. If the fine grained material is used as fill material, the drainage system behind and inside the retaining wall must be well managed. The spaces inside the system that may water to infiltrate, must be collected and delivered outside the system (Koerner, 2005)

2.2 *Geosynthetic material*

The geosynthetic material that is used for earth retaining structure is geogrid, woven and non-woven. Geogrid and woven are used as reinforced elements, and the non-woven is used as separator element.

(a) (b)

Figure 2. (a) Non-Woven and (b) Geogrid

The strength parameter of geosynthetic material is influenced by the field condition, applied load (construction, operational and earthquake loading). The Geosynthetic materials have the specification of their tensile strength. But, during the analysis the ultimate tensile strength must be divided with several reduction factors of geosynthetic as the euation [1] below.

$$T_{design} = \frac{T_{ult}}{RF_{cr} x RF_{id} x RF_{d}} = T_{available} \quad (1)$$

The factors like installation damage (RF_{id}), durability (RF_{d}), and creep (RF_{cr}) must be consider during analysis. The value of the reduction factors of geosynthetic could be taken from the table below based on the use of geosynthetic materials in the field.

Table 2. Reduction factors of geosynthetic material (Koerner, 2007)

Area	Installation Damage	Creep	Durability
Separation	1.1 – 2.5	1.5 – 2.5	1.0 – 1.5
Cushioning	1.1 – 2.0	1.2 – 1.5	1.0 – 2.0
Unpaved roads	1.1 – 2.0	1.5 – 2.5	1.0 – 1.5
Walls	1.1 – 2.0	2.0 – 4.0	1.0 – 1.5
Embankments	1.1 – 2.0	2.0 – 3.5	1.0 – 1.5
Bearing&foundation	1.1 – 2.0	2.0 – 4.0	1.0 – 1.5
Slope	1.1 – 1.5	2.0 – 3.0	1.0 – 1.5
Pavement overlays	1.1 – 1.5	1.0 – 2.0	1.0 – 1.5
Railroads	1.5 – 3.0	1.0 – 1.5	1.5 – 2.0
Flexible form	1.1 – 1.5	1.5 – 3.0	1.0 – 1.5
Silt fences	1.1 – 1.5	1.5 – 2.5	1.0 – 1.5

The value of tensile strength that is used for analysis is the allowable tensile. Hence, the analysis of stability could be conducted.

2.3 *Design of earth retaining structure*

Several steps to design the earth retaining structure is started from the soil investigation like Cone Penetration test (CPT) and deep boring to obtain the stiffness of the soil. The soil is then tested in the laboratory to obtain the physical and mechanical properties like sieve analysis, unit weight (γ), cohesion (c), and friction angle (ϕ). For the backfill materials, must be collected and tested in the laboratory to obtain the optimum dry density and the moisture content.
Analysis could be done by several software like Ms. Excel GGU Stability, Plaxis, ReSSA, etc (Yustian, et al. 2016).

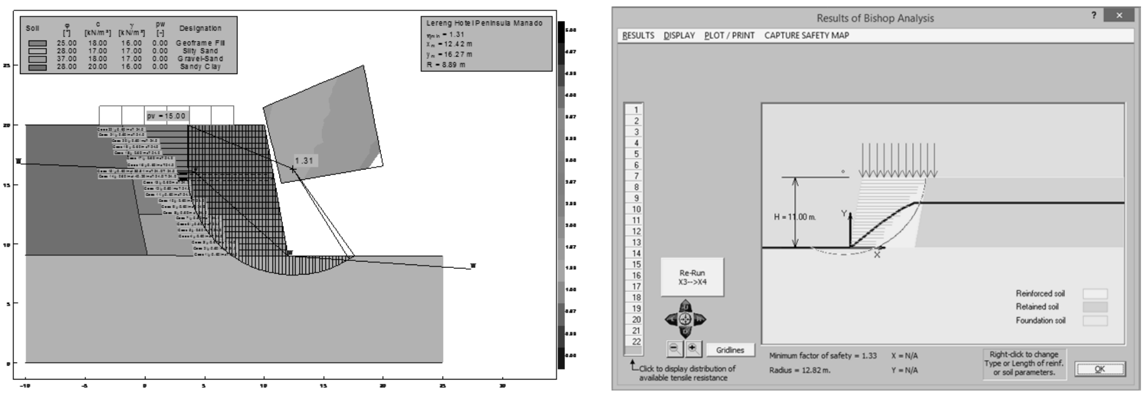


Figure 3. Analysis with GGU Stability and ReSSA 3.0

Tinggi 1 Panel	Tinggi Dinding	H (m)	Lr (m)	Le (m)	L total (m)	Ldesign (m)
1	8	0,5	4,33	0,10	4,43	5,00
	7,5	1	4,04	0,09	4,13	5,00
2	7	1,5	3,75	0,08	3,84	5,00
	6,5	2	3,46	0,08	3,55	5,00
3	6	2,5	3,18	0,08	3,26	5,00
	5,5	3	2,89	0,08	2,97	5,00
4	5	3,5	2,60	0,08	2,68	5,00
	4,5	4	2,31	0,08	2,39	5,00
5	4	4,5	2,02	0,08	2,10	5,00
	3,5	5	1,73	0,08	1,81	5,00
6	3	5,5	1,44	0,07	1,52	6,00
	2,5	6	1,15	0,07	1,23	6,00
7	2	6,5	0,87	0,07	0,94	6,00
	1,5	7	0,58	0,07	0,65	6,00
8	1	7,5	0,29	0,07	0,36	6,00
	0,5	8	0,00	0,07	0,07	6,00

Figure 4. Analysis anchorage of grogrid

The earthquake loading that calculate is the K_{AE} value to substitute the K_A value of static condition. The K_{AE} value is calculated below [2]:

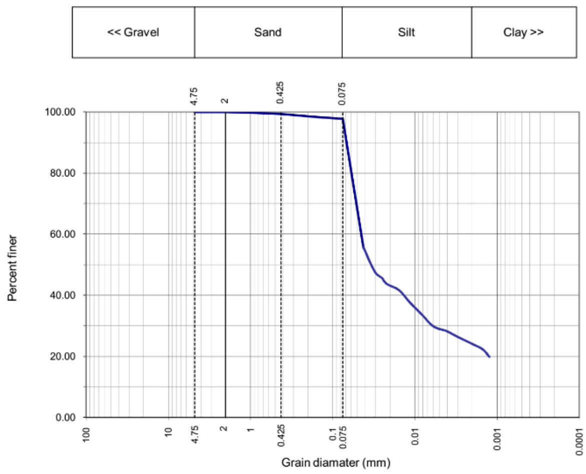
$$K_{AE} = \frac{\cos^2(\varphi - \theta - \beta)}{\cos\theta \cos^2\beta \cos(\delta + \beta + \theta)\left[1 + \left\{\frac{\sin(\delta + \varphi)\sin(\varphi - \theta - i)}{\cos(\delta + \beta + \theta)\cos(i - \beta)}\right\}^{1/2}\right]^2} \quad (2)$$

The earthquake analysis is using pseudostatik analysis where the analysis is simple and suitable to be applied in the earth retaining structure case. Higher value of peak ground acceleration, may increase the K_{AE} value.

3 PROJECT EXPERIENCE

3.1 *Design of earth retaining structure Jakarta*

The design of retaining structure in Jakarta is using laterite soil that is known as red clay soil (*tanah merah*). The grain size distribution is describe as figure below.



Composition	
Sand	2 %
Silt	74 %
Clay	24 %

Figure 5. Grain size analysis

From the sieve analysis, the soil is identified as Clayey Silt. From the compaction test, the optimum dry density is 1,34 gr/cm^3 and the optimum moisture content is 35%. The cohesion of the soil is 50 kPa and the friction angle is 25°. The earth retaining structure is then designed by using these soil parameters.
The first analysis is under static condition where the length of geogrid is conclude below.

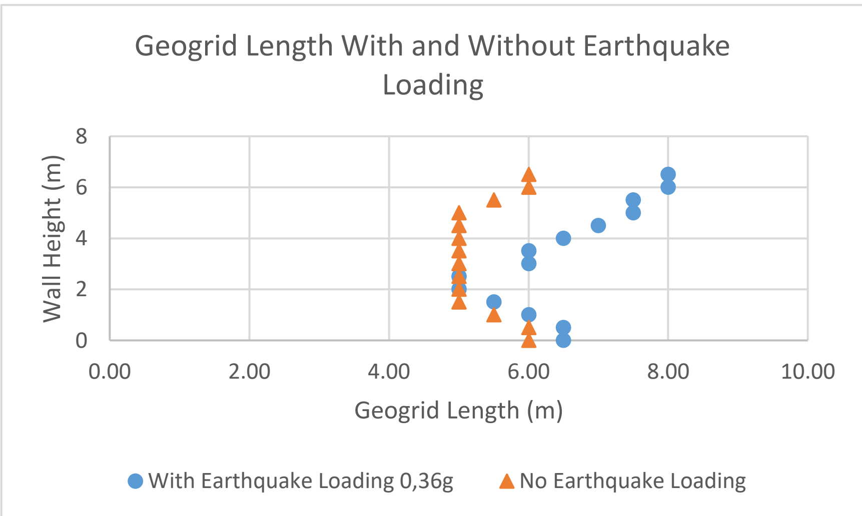


Figure 6. Comparison the geogrid length under static and dynamic condition for laterite soil backfill

From the figure above, the geogrid needs may increase up to 30% due to the earthquake loading. The PGA value of Jakarta is 0,36g with the earth retaining structure is 6,5 meter the maximum length of geogrid is 6 meter, but under earthquake condition the length of geogrid is increase to 8 meter length.

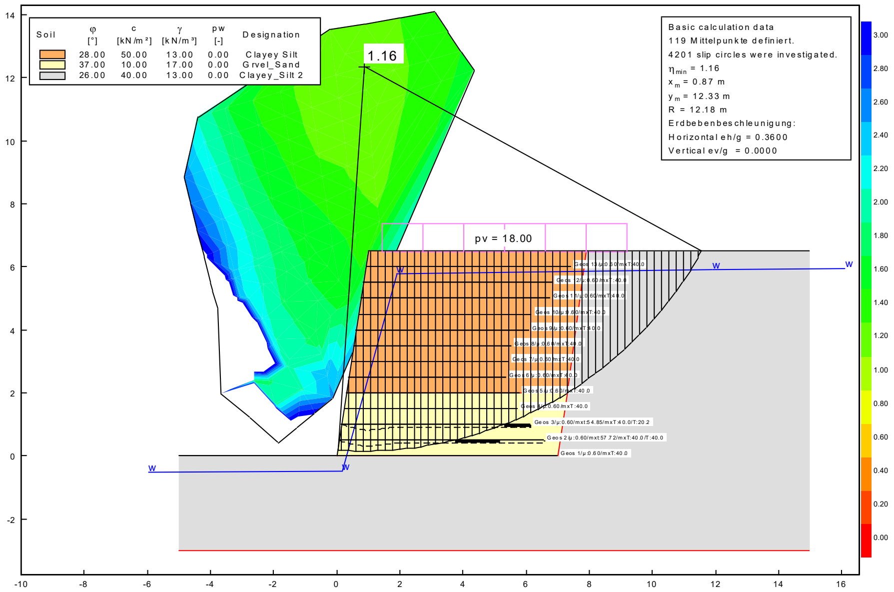


Figure 7. Analysis of global stability

3.2 *Design of Earth Retaining Structure West Sumatera*

The design of retaining structure in West Sumatera is using granular soil that is known as Gravel-Sand soil. the friction angle is 37° and the dry unit weight is 1,7 gr/cm^3. The earth retaining structure was built with 12,5 meter high.

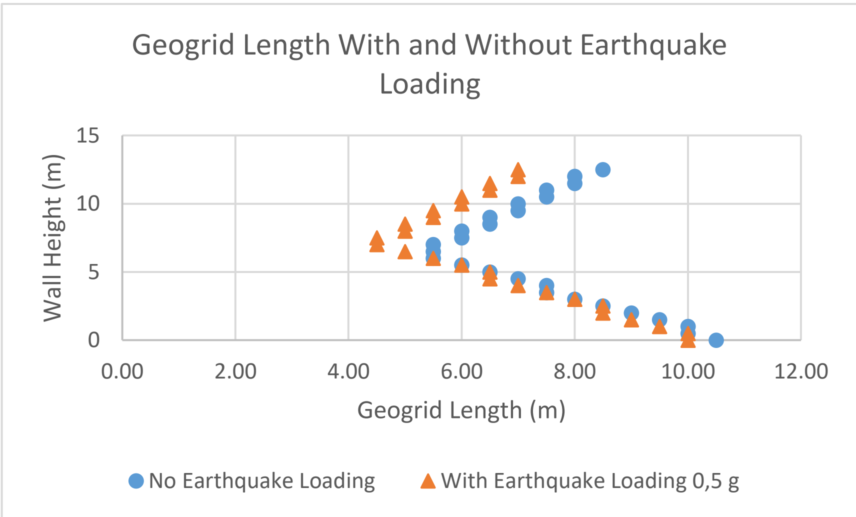


Figure 8. Comparison the geogrid length under static and dynamic condition for granular backfill

From the figure above, the geogrid needs may increase up to 25% due to the earthquake loading. The PGA value of West Sumatera is 0,5 g with the earth retaining structure is 12,5 meter the maximum length of geogrid is 10 meter, but under earthquake condition the length of geogrid is increase to 10,5 meter length.

CONCLUSION

From the analysis and modelisation of geosynthetic for earth retaining structure, the factors like soil backfill material, earthquake loading may cause significant additional of geosynthetic materials need. For fine grained soil for backfill material, the static and dynamic condition may cause significant difference of volume of geogrid that needed up to 30%. On the other hand, the granular backfill soil shows that the difference is only up to 25% of the geogrid volume. Hence, in Indonesia, the calculation of earthquake loading to the design of earth retaining structure is necessary due to the big influence to the stability of the structure.

REFERENCES

Craig R.F. 2007. *Soil Mechanics 7th Edition.* Taylor & Francis Group.
Dandung S.H, Yustian H.S. 2016. Laterite Soil as Backfill Material for Geosynthetics Structures-Challenges and Countermeasures. IGS Conference, Jakarta
Koerner R.M. 2005. Designin with Geosynthetics 5th Edition. Pearson Education, Inc. USA.
Wesley L.D. 2010. Geotechnical Engineering in Residual Soils. John Wiley & Sons. USA
Yustian, H.S., et al. 2016. The Use of Geoframe by Geosynthetic Technology under Earthquake Condition. PIT HATTI. Indonesia