Analysis of Earth Retaining Walls Reinforced by Metallic Strip or Geogrid

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Abstract. Earth retaining wall is a structure used for keeping and maintaining two different ground elevations. In application, sometime the earth retaining walls will combine with reinforcement element to increase the safety factor and any other reasons. Metallic strip and geogrid reinforcement which utilize friction between the fill material and reinforcement elements is one of the common applied. There are passive and active pressures in earth retaining wall analysis, which are influenced by the anchorage length. The analysis will compare the influence of passive pressure to its anchorage length. Moreover, the safety factor of the metallic strip and geogrid reinforcement will be compared with computer software. Since no specific element of metallic strip, the analysis will be conducted through an approach of geogrid and plate element. Passive force calculation on earth fill in the front of the retaining wall with a height of 12 m could shorten the anchorage length by 0.25% for 0.6 m depth; 0.38% for 0.7 m depth; and 0.88% for 1.5 m depth. Hence, passive force does not have to be calculated as it gives a little difference in anchorage length compared to anchorage length calculation which ignores the passive force. Geogrid and plate elements used for modelling metallic strip in PLAXIS gives safety factor with a difference of 0.7%-3.4% and share similar landslide pattern. Therefore, metallic strip can be modelled using an approach of geogrid and plate element. The case study project shows the safety factor of geogrid and metallic strip reinforcement is minimum 1.2. However, geogrid reinforcement has 13.7%-31.4% higher safety factor compared to metallic strip.

Keywords: metallic strip, geogrid, anchorage length, safety factor

1. Introduction

The rapid growth of science and technology has been developed to facilitate the construction execution to be faster, easier and more efficient. Supporting constructions to prevent landslide are needed as construction in steep slope and elevation difference exist. Based on the need, slopes with particular tilt need to be constructed as steep as possible without ignoring the safety factor of the structure.

Slope landslide causes consist of external factors, which are something that causes an increase on landslide risks without any change of the soil shear strength, such as steepening of slope, deepening of soil excavation, river erosion, etc. Besides that, there are also internal factors such as landslide that happens without external contributing factors, or earthquakes. A common example of this condition is the influence of increasing pore pressure in the soil.
To prevent landslides, there are several methods that could be used. One of them is earth retaining wall. Earth retaining wall is a construction that is an important work in a construction project, and can affect the following work and the result of the project. Hence, the construction planning, calculation, and design need to be done accurately. A good analysis is also needed as there are a lot of factors affecting it such as the soil properties, ground water level, seismic condition, etc. Soil, as commonly known, is good in retain compression force, but not tensile stresses. So, one of the methods used for slope reinforcement is Mechanically Stabilized Earth (MSE), which allows additional strength in soil, so it is able to withstand tensile stresses. The reinforcement used could be metallic strip, geogrid, wire mesh, and any other materials.

2. Problem Statement
Earth retaining wall that uses metallic strip is rarely used, especially in Indonesia. This research will analyse the design of metallic strip usage on earth retaining wall. As a comparison, earth retaining wall using geogrid, which is commonly used in Indonesia, will also be analysed. In line with the growth of technology and use of computers in almost every sector, especially in Civil Engineering, the analysis of earth retaining wall will also be complemented with calculation program creation that will be used as a tool to calculate the parameter studies. Apart from that, the computer software will also be used to analyse the overall stability. Since no particular element in computer software that will use in this research to model metallic strip, so it will be analysed with an approach using geogrid and plate elements.

3. Goals and Benefits
The goals of this research are:
- To analyse and design the use of metallic strip and geogrid as a reinforcement on earth retaining walls.
- To compare the safety factor of metallic strip model as plate and geogrid elements in computer software.
- To compare the anchorage lengths with and without influence of passive force.

The expected benefits of this research are:
- Helping the reinforcement choice (metallic strip or geogrid) in reference to their safety factors using computer software.
- Finding out the most suitable metallic strip reinforcement modelling as plate or geogrid elements in computer software.
- Finding out whether passive force needs to be taken into account in earth retaining wall designing.

4. Research Methods
The research approaches that will be conducted are as follows:
1. Literature study that will be used as a reference in report writing and program creation.
2. Formulas and calculation method steps translation to programming language.
3. Program validation checking by comparing the designs resulted from obtained data calculation. If the result obtained does not suit, then program will be revised. If the result obtained suits, then the program will be used as a tool to analyse the parameters.
4. Conclusion drawing and suggestions from the research that has been done.

The research steps in a general scheme are described as a flow chart in Figure 1. It can be seen that there are three steps for analysing the calculation and creating the program:

1. Inserting Calculation Data
   Calculation data used are structure height, dead load working on the structure, data for reinforced soil, retained soil, and subgrade soil such as soil specific gravity, soil cohesion, and soil friction angle. Reinforcement data used are yield stress, horizontal and vertical spacing. For seismic calculation, horizontal maximum acceleration coefficient is needed. Other than
that, safety factor is also needed that consists of shear stability (static & seismic), rotational stability (static & seismic), pull out resistance, bearing capacity, and structure service life.

2. Calculation Process
   The calculation process is divided into three main parts, namely anchorage length calculation, reinforcement material tensile strength calculation, and external, internal, and foundation bearing capacity of determined anchoring length and reinforcement.

3. Calculation Output
   The calculation output is tensile strength of each reinforcement layer, and internal and external safety factor, and foundation bearing capacity.

\textbf{Figure 1} Research Flow Chart

Figure 2 show the process of program creation.

\textbf{Figure 2} Program Creation Flow Chart
Based on the outcome of calculation and modelling, further analysis is conducted using PLAXIS program for determining the safety factor against overall stability.

5. Modelling Process
To ease the calculation process, a program will be created with Visual Basic programming language. The interface of the program is shown in Figure 3.

![Program Layout Interface](image)

The input data are structure height; uniform dead load; soil parameters consisting soil specific gravity, soil cohesion, and soil friction angle; vertical and horizontal spacing; seismic coefficient (only for external stability calculation); and safety factor (static and seismic sliding, static and seismic overturning safety factor, pull out resistance, bearing capacity, and overall stability).

This program can be used for analysing and designing two types of reinforcement, namely extensible (geogrid) and inextensible (metallic strip). The program outputs are layout view and safety factor re-analysis as shown in Figure 4 and 5.

![Safety Factor Analysis Interface](image)

![Design Layout Interface](image)
5.1. Program Validation
Program validation is needed in the creation of the supporting program to determine whether the output of the calculation is appropriate or not. Program validation is carried out by comparing manual calculation with the program output with a calculation deviation < 0.01. Using the available data, these are the result of the program validation.

| The Anchorage Length Requirements | Anchorage Length Without Passive Force (m) | Anchorage Length With Passive Force (m) |
|-----------------------------------|------------------------------------------|---------------------------------------|
|                                  | Manual Calculation | Program Calculation | Manual Calculation | Program Calculation |
| 1. 0.7H                           | 5.60               | 5.60                  | 5.60               | 5.60                  |
| 2. Static Sliding                 | 4.33               | 4.33                  | 4.21               | 4.21                  |
| 3. Seismic Sliding                | 5.42               | 5.42                  | 5.33               | 5.33                  |
| 4. Static Overturning             | 4.42               | 4.42                  | 4.42               | 4.42                  |
| 5. Seismic Overturning            | 5.36               | 5.36                  | 5.37               | 5.37                  |
| 6. Eccentricity                  | 5.11               | 5.11                  | 5.10               | 5.10                  |

**Table 2** Comparison of Metallic Strip Reinforcement Calculation

| Depth (m) | Minimum Metallic Strip Width (m) | Minimum Metallic Strip Thickness (m) |
|-----------|----------------------------------|-------------------------------------|
|           | Manual Calculation | Program Calculation | Manual Calculation | Program Calculation |
| 0.25      | 19.40               | 19.40                     | 0.53               | 0.53                  |
| 0.75      | 19.94               | 19.94                     | 0.70               | 0.70                  |
| 1.25      | 20.53               | 20.53                     | 0.86               | 0.86                  |
| 1.75      | 21.20               | 21.20                     | 1.00               | 1.00                  |
| 2.25      | 21.95               | 21.95                     | 1.12               | 1.12                  |
| 2.75      | 22.81               | 22.81                     | 1.22               | 1.22                  |
| 3.25      | 23.79               | 23.79                     | 1.30               | 1.30                  |
| 3.75      | 24.92               | 24.92                     | 1.36               | 1.36                  |
| 4.25      | 25.08               | 25.08                     | 1.47               | 1.47                  |
| 4.75      | 24.41               | 24.41                     | 1.63               | 1.63                  |
| 5.25      | 24.10               | 24.10                     | 1.77               | 1.77                  |
| 5.75      | 24.17               | 24.17                     | 1.88               | 1.88                  |
| 6.25      | 23.56               | 23.56                     | 2.08               | 2.08                  |
| 6.75      | 22.10               | 22.10                     | 2.43               | 2.43                  |
| 7.25      | 20.82               | 20.82                     | 2.82               | 2.82                  |
| 7.75      | 19.67               | 19.67                     | 3.26               | 3.26                  |
Table 3: Comparison of Geogrid Reinforcement Calculation

| Depth (m) | Minimum Tensile Strength (kN) | Tensile Failure | PullOut Failure |
|----------|-------------------------------|----------------|-----------------|
|          | Manual | Program | Manual | Program | Manual | Program |
| 0.25     | 4.87   | 4.87    | 13.24  | 13.24    | 9.86   | 9.86    |
| 0.75     | 6.84   | 6.84    | 9.43   | 9.43     | 11.38  | 11.38  |
| 1.25     | 8.83   | 8.83    | 7.3    | 7.3      | 12.9   | 12.9   |
| 1.75     | 10.87  | 10.87   | 5.93   | 5.93     | 14.42  | 14.42 |
| 2.25     | 12.95  | 12.95   | 4.98   | 4.98     | 15.94  | 15.94 |
| 2.75     | 15.09  | 15.09   | 4.28   | 4.28     | 17.46  | 17.46 |
| 3.25     | 17.29  | 17.29   | 3.73   | 3.73     | 18.98  | 18.98 |
| 3.75     | 19.58  | 19.58   | 3.29   | 3.29     | 20.5   | 20.5   |
| 4.25     | 21.96  | 21.96   | 2.94   | 2.94     | 22.03  | 22.03 |
| 4.75     | 24.44  | 24.44   | 2.64   | 2.64     | 23.55  | 23.55 |
| 5.25     | 27.06  | 27.06   | 2.38   | 2.38     | 25.07  | 25.07 |
| 5.75     | 29.81  | 29.81   | 2.16   | 2.16     | 26.59  | 26.59 |
| 6.25     | 32.74  | 32.74   | 1.97   | 1.97     | 28.11  | 28.11 |
| 6.75     | 35.85  | 35.85   | 1.8    | 1.8      | 29.63  | 29.63 |
| 7.25     | 39.19  | 39.19   | 1.65   | 1.65     | 31.15  | 31.15 |
| 7.75     | 42.79  | 42.79   | 1.51   | 1.51     | 32.67  | 32.67 |

Table 4: Comparison of Foundation Bearing Capacity Calculation

| Foundation Bearing Capacity Safety Factor | Without Passive Force | With Passive Force |
|------------------------------------------|-----------------------|-------------------|
|                                          | Manual Calculation    | Program Calculation | Manual Calculation | Program Calculation |
| Metallic Strip Reinforcement             | 5.63                  | 5.63              | 6.52              | 6.52              |
| Concrete Anchor Reinforcement            | 5.63                  | 5.63              | 6.52              | 6.52              |
| Geogrid Reinforcement                    | 5.63                  | 5.63              | 6.52              | 6.52              |

Table 1 to Table 4 show the same output between manual and program calculation. Thus, the program is appropriate to be used for analysing parameter comparison.
5.2. Influence of Passive Force in Reinforcement Length
Passive force is an additional force that occurs because of an earth fills in the front of the structure or because of the structure embedded (d). In passive force calculation, the embedded depth (d) varies from 0 m (for calculation neglecting passive force); 0.6m; 0.7m; 0.8m; 0.9m; 1.0m; 1.1m; 1.2m; 1.3m; 1.4m and 1.5m. The following table shows the summary of reinforcement length calculation to the structure embedded depth.

Table 5. Comparison of Foundation Bearing Capacity Stability Calculation

| Anchorage Length Requirements | Anchorage Length (m) |
|------------------------------|----------------------|
|                              | d=0     | d=0.6    | d=0.7    | d=0.8    | d=0.9    | d=1.0    | d=1.1    | d=1.2    | d=1.3    | d=1.4    | d=1.5    |
| 1. Static sliding            | 6.06    | 5.98     | 5.96     | 5.92     | 5.89     | 5.85     | 5.80     | 5.75     | 5.70     | 5.64     | 5.58     |
| 2. Seismic sliding           | 7.81    | 7.75     | 7.73     | 7.70     | 7.76     | 7.74     | 7.61     | 7.57     | 7.53     | 7.48     | 7.43     |
| 3. Static overturning        | 6.32    | 6.32     | 6.32     | 6.32     | 6.32     | 6.32     | 6.31     | 6.31     | 6.31     | 6.30     |          |
| 4. Seismic overturning       | 7.93    | 7.91     | 7.90     | 7.89     | 7.88     | 7.88     | 7.87     | 7.87     | 7.87     | 7.86     | 7.86     |
| 5. Eccentricity              | 7.44    | 7.44     | 7.44     | 7.44     | 7.44     | 7.44     | 7.44     | 7.44     | 7.44     | 7.43     | 7.43     |
| Minimum length:              | 7.93    | 7.91     | 7.90     | 7.89     | 7.88     | 7.88     | 7.87     | 7.87     | 7.87     | 7.86     | 7.86     |

Figure 6 Illustration of Passive Force in Structure
The above graph shows that there is a similar anchorage length for different embedded depth. The embedded depth of 0.9 m and 1.0 m have the same anchorage length, which is 7.88 m. For the embedded depth of 1.1 m; 1.2 m and 1.3 m, the anchorage length is 7.87 m. Thus, an increase in embedded depth results in constant anchorage length. In other words, an increment to particular depth will not or only influence a little amount to the anchorage length. Based on the validation result and modelling analysis that have been done, the program created is able to be applied to real-case scenario.

6. Case Study
The case study data was taken from a fly over construction in Jakarta that needs a retaining wall structure. The following figures show the top and side view of the fly over.

The points to be reviewed are 1-West, 2-West, 1-East and 2-East. The data that will be used in designing the earth retaining wall for each location is shown below.
Table 6 Soil Parameter Input of Case Study

| Location     | 1W  | 2W  | 1E  | 2E  |
|--------------|-----|-----|-----|-----|
| Height       | 4.7m| 5.3m| 2.7m| 4.9m|

Reinforced Backfill

|       | 20kN/m³ | 20kN/m³ | 20kN/m³ | 20kN/m³ |
|-------|---------|---------|---------|---------|
| γ     | 0kN/m²  | 0kN/m²  | 0kN/m²  | 0kN/m²  |
| c     | 35°     | 35°     | 35°     | 35°     |

Retained Backfill

|       | 20kN/m³ | 20kN/m³ | 20kN/m³ | 20kN/m³ |
|-------|---------|---------|---------|---------|
| γ     | 0kN/m²  | 0kN/m²  | 0kN/m²  | 0kN/m²  |
| c     | 35°     | 35°     | 35°     | 35°     |

Foundation Soil

|       | 16kN/m³ | 16kN/m³ | 16kN/m³ | 16kN/m³ |
|-------|---------|---------|---------|---------|
| γ     | 3.75kN/m² | 10kN/m² | 3.125kN/m² | 15kN/m² |
| c     | 30°     | 30°     | 30°     | 30°     |

By using the program, the layout design results are shown in Figure 9 to Figure 16. The layout was designed using two types of reinforcements, namely geogrid and metallic strip. The design recalculates internal and external stability safety factors that are shown in Table 7 to Table 11.

Figure 9 Earth Retaining Wall Design on Point A1W with Geogrid Reinforcement

Figure 10 Earth Retaining Wall Design on Point A1W with Metallic Strip Reinforcement
Figure 11 Earth Retaining Wall Design on Point A1E with Geogrid Reinforcement

Figure 12 Earth Retaining Wall Design on Point A1E with Metallic Strip Reinforcement

Figure 13 Earth Retaining Wall Design on Point A1W with Geogrid Reinforcement

Figure 14 Earth Retaining Wall Design on Point A2W with Metallic Strip Reinforcement

Figure 15 Earth Retaining Wall Design on Point A2E with Geogrid Reinforcement

Figure 16 Earth Retaining Wall Design on Point A2E with Metallic Strip Reinforcement
Table 7 External Stability Safety Factor

| Criteria                     | Location       | A1W Geogrid | A1W Metallic Strip | A2W Geogrid | A2W Metallic Strip | A2E Geogrid | A2E Metallic Strip | Note               |
|------------------------------|----------------|-------------|--------------------|-------------|--------------------|-------------|--------------------|--------------------|
| 1. 0.7H (FHWA)               | Safety Factor  | 3.30        | 3.30               | 3.00        | 3.00               | 3.80        | 3.80               | ≥ 0.7H OK          |
| 2. Sliding (static)          | Safety Factor  | 2.10        | 2.10               | 2.72        | 2.72               | 2.22        | 2.22               | ≥ 1.5 OK           |
| 3. Sliding (seismic)         | Safety Factor  | 1.37        | 1.37               | 1.89        | 1.89               | 1.43        | 1.43               | ≥ 1.125 OK         |
| 4. Overturning (static)      | Safety Factor  | 3.33        | 3.33               | 6.47        | 6.47               | 3.63        | 3.63               | ≥ 2 OK             |
| 5. Overturning (seismic)     | Safety Factor  | 1.92        | 1.92               | 4.13        | 4.13               | 2.06        | 2.06               | ≥ 1.5 OK           |
| 6. Eccentricity              | Safety Factor  | 0.41        | 0.41               | 0.17        | 0.17               | 0.44        | 0.44               | < 1/6L OK          |
| 7. Bearing Capacity          | Safety Factor  | 4.64        | 4.64               | 7.57        | 7.57               | 5.99        | 5.99               | ≥ 2 OK             |

Table 8 Internal Stability Safety Factor on Point A1W

| Level | Location A1W | PullOut SF Geogrid | PullOut SF Metallic Strip | Note               |
|-------|---------------|--------------------|---------------------------|--------------------|
| 0.8   | Geogrid 3.38  | Metallic Strip 7.72|                           | ≥ 1.5 OK           |
| 1.4   | Geogrid 2.49  | Metallic Strip 5.86|                           | ≥ 1.5 OK           |
| 2     | Geogrid 1.94  | Metallic Strip 4.72|                           | ≥ 1.5 OK           |
| 2.6   | Geogrid 1.56  | Metallic Strip 3.92|                           | ≥ 1.5 OK           |
| 3.2   | Geogrid 2.24  | Metallic Strip 3.34|                           | ≥ 1.5 OK           |
| 3.8   | Geogrid 1.86  | Metallic Strip 2.87|                           | ≥ 1.5 OK           |
| 4.4   | Geogrid 1.55  | Metallic Strip 2.49|                           | ≥ 1.5 OK           |

Table 9 Internal Stability Safety Factor on Point A1E

| Level | Location A1E | PullOut SF Geogrid | PullOut SF Metallic Strip | Note               |
|-------|---------------|--------------------|---------------------------|--------------------|
| 0.6   | Geogrid 3.81  | Metallic Strip 7.09|                           | ≥ 1.5 OK           |
| 1.2   | Geogrid 2.72  | Metallic Strip 5.21|                           | ≥ 1.5 OK           |
| 1.8   | Geogrid 2.07  | Metallic Strip 4.10|                           | ≥ 1.5 OK           |
| 2.4   | Geogrid 1.64  | Metallic Strip 3.36|                           | ≥ 1.5 OK           |
### Table 10 Internal Stability Safety Factor on Point A2W

| Level | Location A2W | Note | PullOut SF | Note |
|-------|--------------|------|------------|------|
|       | Tensile SF   |       |            |      |
|       | Geogrid      | Steel Strip | ≥ 1.5 OK | 6.69 | 3.94 | ≥ 2 OK |
| 0.8   | 3.39         | 6.91  |           |      |      |      |
| 1.4   | 2.51         | 5.27  | ≥ 1.5 OK  | 8.13 | 3.80 | ≥ 2 OK |
| 2     | 1.96         | 4.27  | ≥ 1.5 OK  | 9.56 | 3.64 | ≥ 2 OK |
| 2.6   | 1.60         | 3.59  | ≥ 1.5 OK  | 11.00 | 3.48 | ≥ 2 OK |
| 3.2   | 2.65         | 3.08  | ≥ 1.5 OK  | 12.43 | 3.3  | ≥ 2 OK |
| 3.8   | 2.23         | 2.69  | ≥ 1.5 OK  | 13.87 | 3.11 | ≥ 2 OK |
| 4.4   | 1.9          | 2.37  | ≥ 1.5 OK  | 15.3 | 2.9  | ≥ 2 OK |
| 5     | 1.62         | 2.11  | ≥ 1.5 OK  | 16.74 | 2.68 | ≥ 2 OK |

### Table 11 Internal Stability Safety Factor on Point A2E

| Level | Location A2E | Note | PullOut SF | Note |
|-------|--------------|------|------------|------|
|       | Tensile SF   |       |            |      |
|       | Geogrid      | Steel Strip | ≥ 1.5 OK | 5.32 | 3.94 | ≥ 2 OK |
| 0.4   | 7.67         | 9.29  |           |      |      |      |
| 1     | 5.3          | 6.62  | ≥ 1.5 OK  | 6.75 | 3.8  | ≥ 2 OK |
| 1.6   | 4            | 5.16  | ≥ 1.5 OK  | 8.19 | 3.66 | ≥ 2 OK |
| 2.2   | 3.17         | 4.22  | ≥ 1.5 OK  | 9.62 | 3.5  | ≥ 2 OK |
| 2.8   | 2.58         | 3.56  | ≥ 1.5 OK  | 11.06 | 3.34 | ≥ 2 OK |
| 3.4   | 2.14         | 3.05  | ≥ 1.5 OK  | 12.49 | 3.16 | ≥ 2 OK |
| 4     | 1.8          | 2.65  | ≥ 1.5 OK  | 13.93 | 2.97 | ≥ 2 OK |
| 4.6   | 1.51         | 2.32  | ≥ 1.5 OK  | 15.36 | 2.76 | ≥ 2 OK |

An analysis of overall stability is conducted using the earth retaining wall design result above using PLAXIS. The process is started by modelling the structure in PLAXIS as shown in figure 17 – figure 19 below.

![Earth Retaining Wall Model on Point A1W with Geogrid Reinforcement](image-url)
Figure 18 Earth Retaining Wall Model on Point A1W with Metallic Strip Reinforcement (Geogrid Element)

Figure 19 Earth Retaining Wall Model on Point A1W with Metallic Strip Reinforcement (Plate Element)

The safety factor resulted by Plaxis is shown in Table 11 below:

| Location | Metallic Strip Reinforcement Safety Factor | Geogrid Reinforcement Safety Factor |
|----------|-------------------------------------------|----------------------------------|
| A1W      | 1.372 Geogrid Modelling, 1.390 Plate Modelling | 1.771 |
| A2W      | 1.276 Geogrid Modelling, 1.292 Plate Modelling | 1.777 |
| A1E      | 2.165 Geogrid Modelling, 2.180 Plate Modelling | 2.470 |
| A2E      | 1.357 Geogrid Modelling, 1.403 Plate Modelling | 1.813 |

Table 11 Comparison of Geogrid and Metallic Strip Safety Factor

Figure 20 Safety Factor against Overall Stability using Geogrid and Metallic Strip Reinforcement

Table 11 and Figure 20 above show that the safety factor of geogrid modelled-metallic strip reinforcement and plate modelled-metallic strip using PLAXIS result in similar safety factor. The difference is in between 0.016 - 0.046 or around 0.7% to 3.4%. The deformation patterns of the geogrid and plate model are similar (see Figure 22). Thus, it could be concluded that both of the approach could be used as an approach to model metallic strip as reinforcement in earth retaining wall. Other than that, diagram above shows that geogrid reinforcement has higher average safety factor of 0.3 – 0.5, with percentage 13.7% - 31.4%.
7. Conclusion
Based on the research that has been conducted, then it could be concluded that:

- The calculation of passive force in earth fill in front end of the earth retaining wall structure with 12 m height could shorten the length of anchoring as much as 0.25% for 0.6 m depth of planting; 0.38% for 0.7 m depth; and 0.88% for depth of 1.5 m. Therefore, the passive force does not have to be taken into account because it gives little difference in anchoring length compared to the anchoring length neglecting the passive force.

- Geogrid and plate elements that are used for modelling metallic strip in PLAXIS program gives a small difference in safety factor as much as 0.7% to 3.4%, and has similar deformation pattern, so metallic strip can be modelled using either geogrid or plate elements.

- In the case study analysis using PLAXIS, it is known that all safety factors of earth retaining wall reinforcement using geogrid and metallic strip are at least 1.2. But, geogrid-reinforced earth retaining wall has a higher safety factor than metallic strip as high as 13.7 – 31.4%, so using geogrid as a reinforcement in earth retaining wall will have safer structure.
References

[1] Allen, Tony et.al. (2001). Development of The Simplified Method for Internal Stability Design of Mechanically Stabilized Earth Walls. United States of America: Washington State Department of Transportation.

[2] American Association of State Highway and Transportation Officials. (1996). Standard Specifications for Highway Bridges. (sixteenth edition).

[3] Bonaparte, R., Holtz, R. D., dan Giroud, J. P. (1987). Soil Reinforcement Design Using Geotextiles and Geogrids. Proceedings of Geotextile Testing and the Design Engineer. Philadelphia. pp 69-116.

[4] Brooks, Hugh. (2010). Basics of Retaining Wall Design (eighth edition). United States of America: HBA Publications.

[5] Coduto, D. P. (2001). Foundation Design Principles and Practices (second edition). New Jersey: Prentice Hall.

[6] Das, Braja M. (2006). Principles of Geotechnical Engineering (fifth edition). Canada: Thomson.

[7] Gouw, Tjie-Liong. (1996). Dinding Perkuatan Tanah Mechanically Stabilized Earth (MSE Wall). Jakarta.

[8] Gouw, Tjie Liong. (2009). Plaxis Standard Course. Jakarta.

[9] Gouw, Tjie Liong. (2011). Earth Pressures. Slope Stability. Deep Excavation and Liquefaction Analysis. Jakarta.

[10] Halvorson, Michael. (2008). Microsoft Visual Basic 2008 Step by Step. United States of America: Microsoft Press.

[11] Hardiyatmo, H. C. (2002). Teknik Pondasi 1 (edisi kedua). Yogyakarta: Beta Offset.

[12] Jones, Colin J.F.P. (1996). Earth Reinforcement & Soil Structures (new edition). London: Thomas Telford.

[13] Koerner, R. M. (2005). Designing with Geosynthetic. 5th ed. New Jersey: Pearson Prentice Hall.

[14] Lee C.H. (2000). Design and Construction of A 9.6 m High Segmental Wall. Proceedings of the 2nd Asian Geosynthetics Conference. Kuala Lumpur. Malaysia. pp. 19-24.

[15] National Cooperative Highway Research Program (1987). Reinforcement of Earth Slopes and Embankments.

[16] National Cooperative Highway Research Program (2008). Seismic Analysis and Design of Retaining Walls. Buried Structures. Slopes. and Embankments.

[17] Petroutsos, Evangelos dan Mark Ridgeway (2008). Mastering Microsoft Visual Basic 2008. Indianapolis: Wiley Publishing.

[18] PLAXIS b.v. (2002). PLAXIS Version 8 Manual. Netherlands: A.A. Balkema Publishers.

[19] Tennessee Department of Transportation. (2010). Earth Retaining Structures Manual. (second edition).

[20] Tjoamir, Yusan Pieter. (2008). Analisa Stabilitas Lereng Yang Diperkuat Soail Nailing Dengan Menggunakan PLAXIS v8.6. Jakarta: BINUS University.

[21] U.S. Department of Transportation – Federal Highway Administration. (2009). Mechanically Stabilized Earth Walls and Reinforced Soil Slopes.

[22] Yohanes. (2005). Penggunaan Program PLAXIS Untuk Menganalisa Secant Pile Sebagai Dinding Penahan Tanah. Jakarta: BINUS University.