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Strength Analysis of Soil Retaining Wall Using Numerical Method of Manokwari Landfill

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Abstract The city growth and development with all the dynamics are currently going on quite rapidly demand, the provision of facilities and city infrastructure is getting better and more adequate. Urban infrastructure development, especially those related to waste management, is an urgent need in the context of efforts to prevent environmental pollutions. Several factors need to be considered to building infrastructure, one of which is the security factor. The safety factor is a major factor in the construction of the retaining wall. The purpose of this study is to investigate mechanical effects of soil retaining wall in the three types of designs of the landfills by 2D finite element analysis. The results could provide a reference for building to withstand the active lateral compressive forces of soil and water. The contribution of this study is sufficient for providing a functional strength of retaining walls. FEM (Finite Element Method) is a numerical method that is often used in analysing the compressive strength of retaining wall. In this study, 2D analysis is used to determine the compressive strength of the soil on the retaining wall of the landfill in Manokwari City. The retaining wall in this study is varied based on these three forms of the retaining wall. It is according to the literature and the three different finite element numbers based on the software. Ansys software is used to simulate the compressive strength of retaining walls against the ground. The results found were compared. The results obtained indicated that the geometry design 2 has a better safety value when compared to the others. This is reinforced by the results of the numerical calculations obtained, namely A2 = 29497.3 N/mm^2, B2 = 42579.2 N/mm^2, and C2 = 82138.8 N/mm^2.

Keywords Retaining Wall, Compressive Strength, Finite Element Method (FEM), Ansys

1. Introduction

Garbage is a problem that is often faced by residents in Manokwari city – Indonesia, such as locations close to settlements and rivers, limited and inadequate infrastructure/ facilities, only open dumping operations without compaction or land cover. Urban infrastructure development, especially those related to solid waste management, is an urgent need in the context of efforts to prevent environmental pollution [1]. Several obstacles encountered in various urban areas, including Manokwari Regency and its surrounding areas, have resulted in the handling of solid waste problems, especially landfills (TPA) which have not received proportional priority. One of the infrastructure development efforts to tackle waste is creating landfill that has a large capacity. The construction of a retaining wall is one of the efforts to create a landfill. It is used to prevent environmental pollution. Retaining walls are a type of civil construction that is built to withstand the active lateral compressive forces of soil and water. Some of the functions of retaining walls are urban construction [2], holding landfills [3–5], creating basements [6], and retaining mountainous soils [7].

Several designs of retaining walls that have been widely used include Gravity Retaining walls [2, 7-12], Cantilever Retaining walls [8], Counter fort Retaining walls [3, 8, 13-18], Reinforced Soil Retaining walls [5, 6, 8, 19-25], and anchored bulkhead [8, 19]. Along with its development, the retaining wall design has been added according to applications including the Gravity Retaining wall design [4, 16, 19, 26-28] and Counter fort Retaining wall [19, 29].

Based on the requirements of PN-EN 1997-1: 2008 Eurocode 7: Geotechnical design. Part 1. General rules, retaining walls are distinguished by the material used, the load transfer method, workload, and production technology [19]. In constructing a retaining wall, the most important thing is to know the active ground pressure [2, 7, 9, 10, 13], the seismic pressure [3], the passive soil pressure [6, 20-22], the active soil pressure [23, 26], static and dynamic soil pressure [4], and lateral pressure [5].

In conducting a strength analysis on soil retaining walls, there are several methods in determining it, such as analytical and numerical methods. To make it easier to get the values of the most important things, a numerical method is needed. The numerical methods commonly used are the finite element method [11, 12, 14-18, 24, 27, 29-31] and the limit equilibrium method [25].

The finite element method is a numerical procedure that can be used to find a solution to most engineering problems involving stress, heat transfer, electromagnetic and fluid flow analysis. It contains many complex forms of domain problems which can be solved easily [32].

In general, the finite element method (for some elements) is defined as [32]:

$$[K]T=\mathrm{f} \qquad (1)$$

where [K] is the matrix condition, or it can also be elaborated as:

$$[\mathbf{K}] = K_{ij} = \int_{\Omega} \left[K_x \frac{\partial N_i}{\partial x}\frac{\partial N_i}{\partial x} + \frac{\partial N_i}{\partial y}\frac{\partial N_i}{\partial y} d\Omega\right] \qquad (2)$$

While N_i and N_j are the shape functions of the Moving Least Squares (MLS) row i and column j, respectively, T is a vector that describes nodal displacement and f is a vector that describes nodal forces and external forces, or it can also be described as:

$$\boldsymbol{f} = F_i = \int_{\Omega} Q(x,y)N_i d\Omega + \int_{\Gamma} \bar{q}N_i d\Gamma \qquad (3)$$

Several geometric designs in this study are presented in order to determine which design is the best applied to the Manokwari Landfill. Each design is occupied from several literatures. In the literature, the nature and design of retaining walls are determined. All geometric designs are completed using numerical methods. The results obtained are compared with the literature that has been made previously.

2. Numerical Analysis

2.1. Analysed Retaining Wall Variants

Figure 2 analyzed retaining wall design. Each design has a different structure and height according to the literature. Figure 1 shows the retaining wall design that has been studied [1]. In its application, the design is a comparison that has been used for the retaining wall at the Manokwari Landfill.

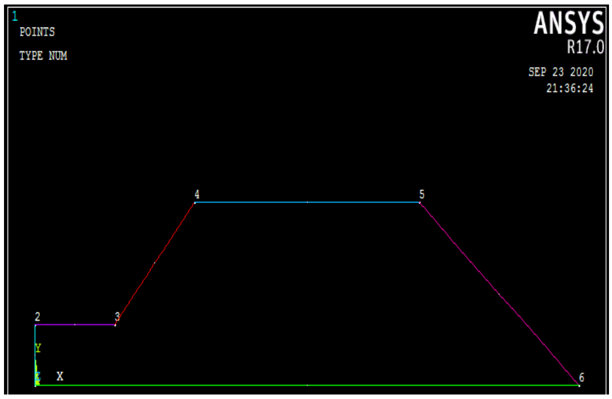


Figure 1. Design of retaining walls used at the Manokwari Landfill [1]

The design consists of height and width of a retaining wall of 6.5m and 17m. This design has long been used by the landfill manager to hold landfill and used by the manager since 2007. Figure 2 shows the design of the second retaining wall that has been studied by [27]. In its application, this design is used to model a retaining wall of landfills in Iraq and has been used to analyze earthquake resistance from 1900-1988. It consists of a height and width of 3m and 1.1m, respectively. Figure 3 shows the second retaining wall design that has been studied by [28]. In its application, it is used to retain land around the PT Trakindo area, Maumbi village, North Minahasa district and has experienced a shift and instability in the construction of the retaining wall. The design consists of a height and width of 7.96m and 2.6m, respectively.

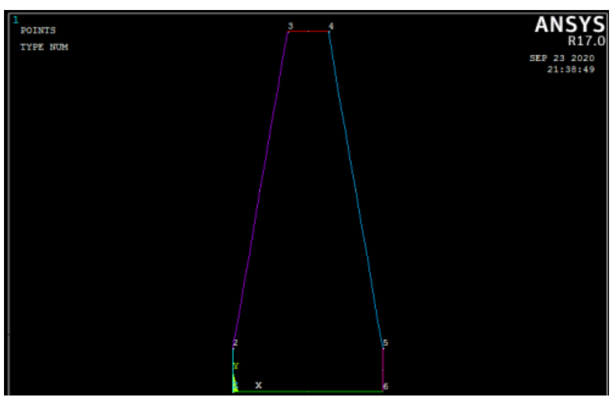


Figure 2. Retaining wall design 2 [27]

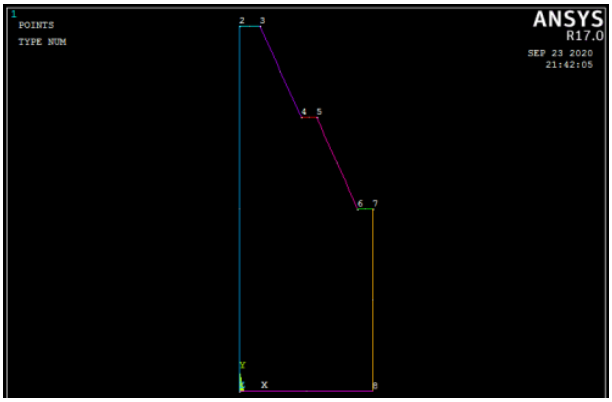
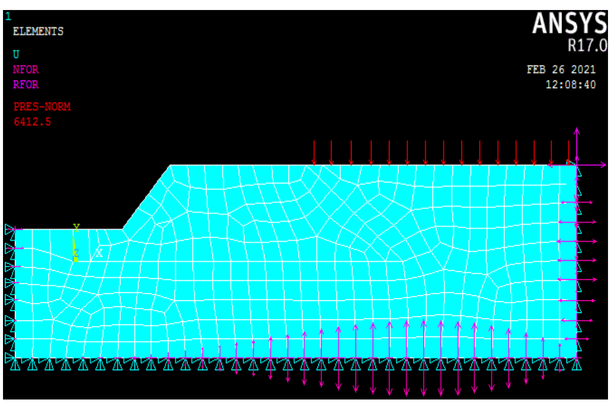


Figure 3. Retaining wall design 3 [28]

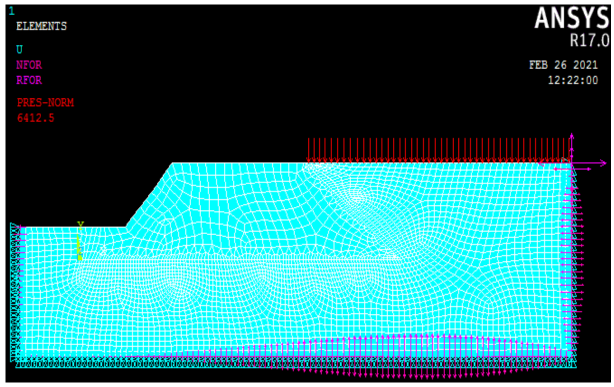
2.2. Numerical Models

In this study, all retaining walls were modelled using Ansys 17.0 software running on the ASUS L451 RAM 12 GB computer. Material properties and geometry were taken from various literatures and the number of finite elements was determined by software [1, 27, 28]. The calculation used in this study is a simple calculation. Figure 4 shows geometry 1, divided into three types having different number of finite elements, A1 310 elements, B1 3584 elements and C1 57112 elements. Figure 5 shows geometry 2, divided into three types having different number of finite elements, A2 292 elements, B2 3411 elements and C2 42021 elements. And figure 6 for geometry 3, it is divided into three types having different number of finite elements, A3 335 elements, B3 4022 elements and C3 52817 elements.

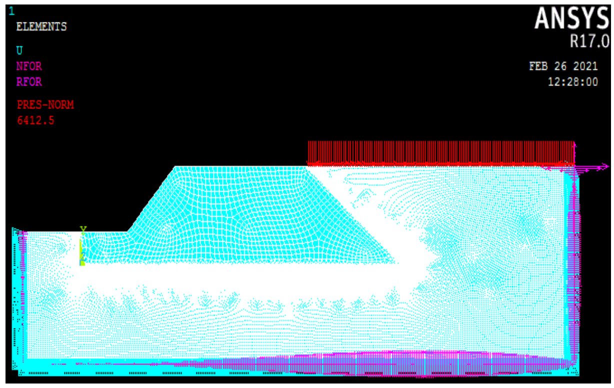
The three models have boundary conditions according to literature [1]. Each of them is given a pressure of 6412.5 Kg/m^2 with the boundary conditions for both sides and the bottom part considered constant in all directions. The results obtained are then compared in order to obtain the safety factor value of which retaining wall is the best.



A1

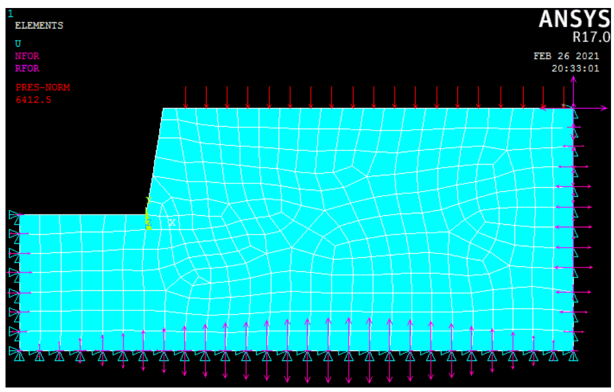


B1

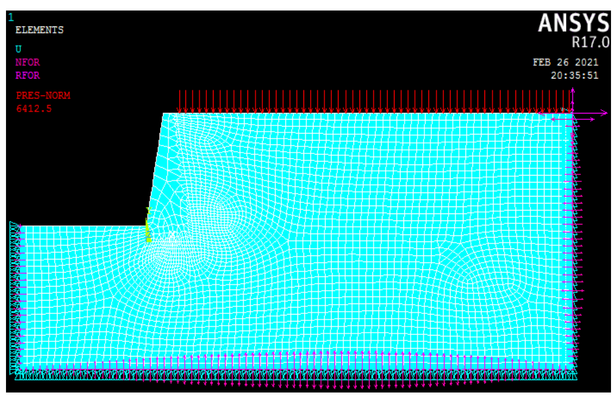


C1

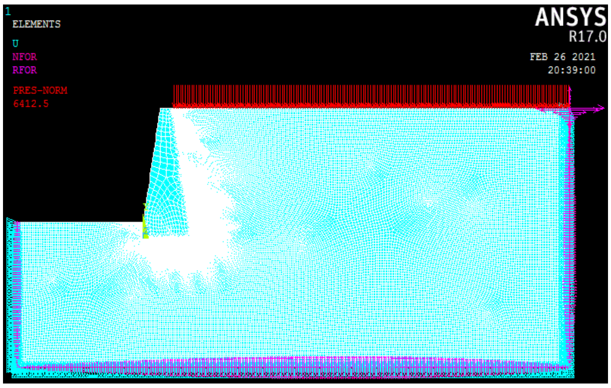
Figure 4. Geometry design 1 consisting of A1, B1, and C1



A2

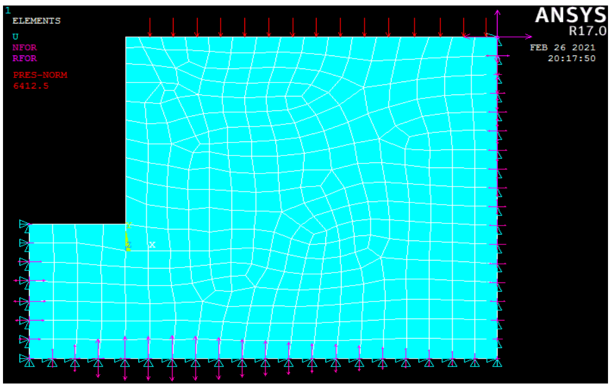


B2

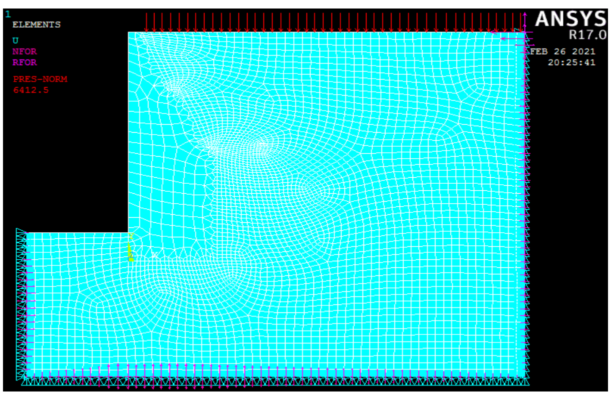


C2

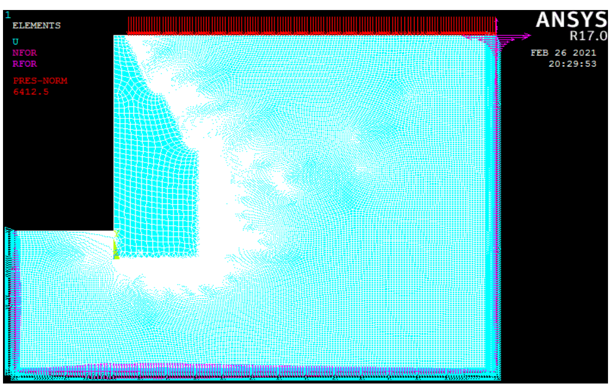
Figure 5. Geometry design 2 consisting of A2, B2, and C2



A3



B3



C3

Figure 6. Geometry design 3 consisting of A3, B3, and C3

3. Obtained Results

From the results of numerical analysis, a map of the displacement distribution and stress distribution in each of the retaining wall geometries is obtained. From some of these geometries, it can be seen that the retaining structure and soil, and also horizontal and vertical displacement are well distributed in each of the geometries presented. Each stress distribution map produced by geometries 1, 2, and 3 is shown in Figures 7, 8, and 9.

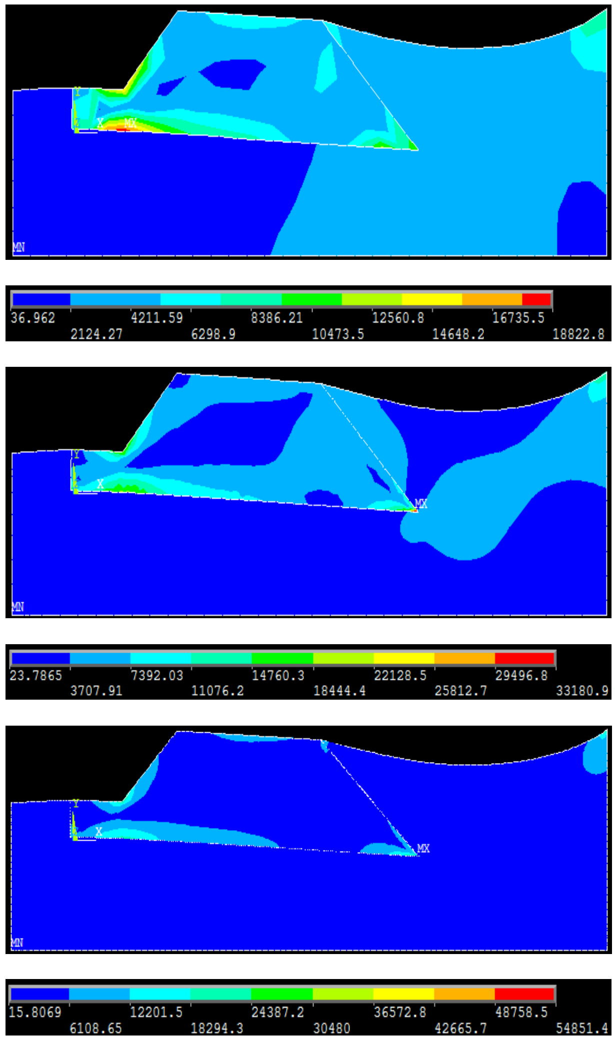
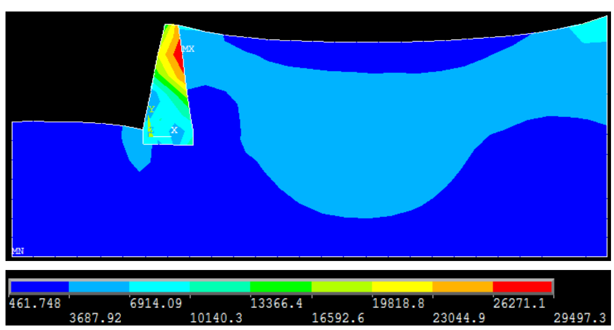


Figure 7. The contour of retaining wall geometry 1 varies A1, B1, and C1



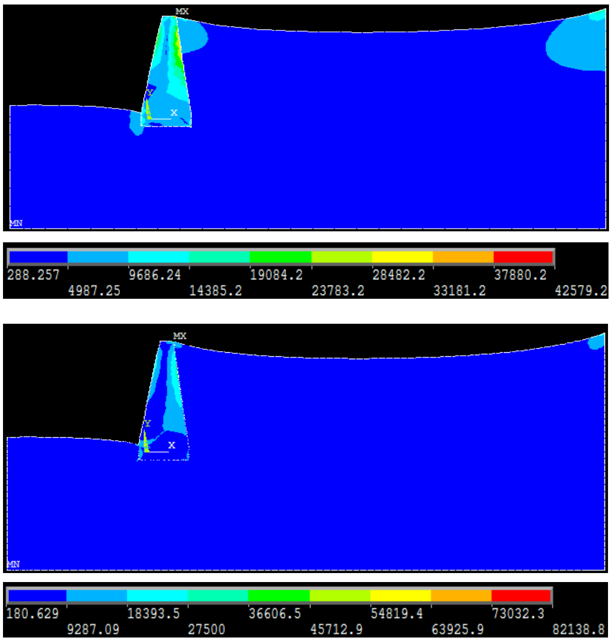


Figure 8. Contour of retaining wall geometry 2 varies A2, B2, and C2

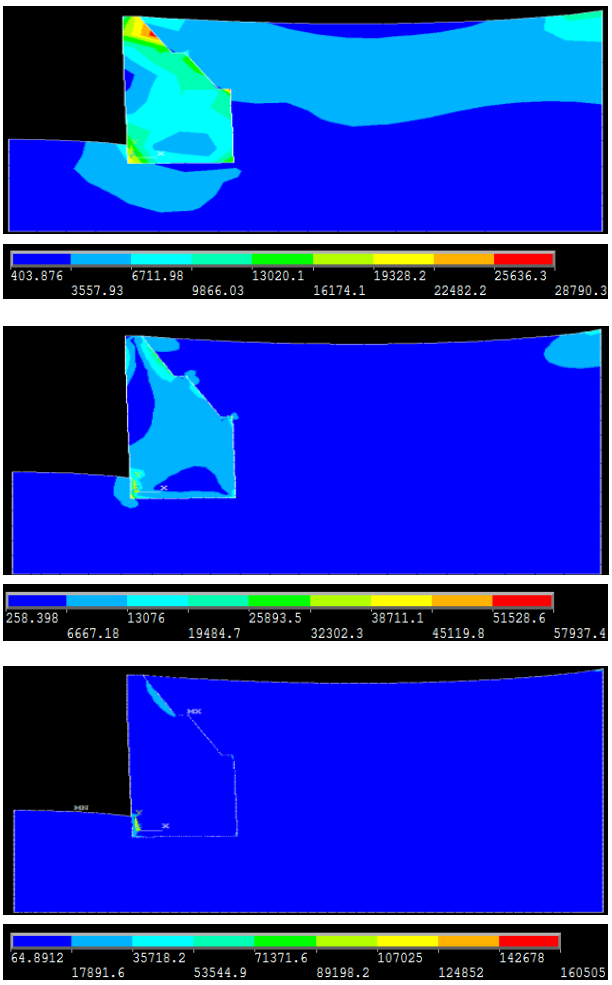


Figure 9. Contour of retaining wall geometry 3 varies A3, B3, and C3

Figure 10 showed the amount of stress in each geometry. The maximum values acquired by A1, B1, and C1 for each of these geometries were 18822.8 N/mm^2, 33180.9 N/mm^2, and 54851.4 N/mm^2. then A2, B2, and C2 were 29497.3 N/mm^2, 42579.2 N/mm^2, and 82138.8 N/mm^2. Furthermore, for A3, B3, and C3 each of these geometries were 28790.3 N/mm^2, 57937.4 N/mm^2, and 160505 N/mm^2 respectively. From these results, it was discovered that the number of elements given to each geometry greatly affects the resulting value. The more element values, the higher the resulting calculation value. Therefore, the number of elements highly affected the number of calculations when applying the numerical method. In addition, the design of the comparison presented was very influential.

Based on the calculation results, geometry 1 had a stress result that increases as the number of elements increases. C1 had 57112 elements, which was the highest number compared to A1 and B1. The value obtained by C1 was 54851.4 N/mm^2. This result was shown as well by the geometry design 2 and 3, with C2 of 82138.8 N/mm^2 and C3 of 160505 N/mm^2 respectively. These results were in accordance with the equations in the finite element method. Conversely, if the number of elements used was less, the calculation results would be small.

Of the three comparing models, geometry 1 had a good stress distribution value based on the results of numerical calculations. The geometry model 1 had very small shifts and stresses compared to the two geometries presented. This shows that the geometry model 1 had a good material and geometric properties when applied to the surrounding environment. In addition to geometry model 1, geometry model 2 also had good material and geometric properties when applied to landfills compared to geometry model 3. This occurred since the results of the stress distribution in Figure 10 showed a small value compared to geometry model 3.

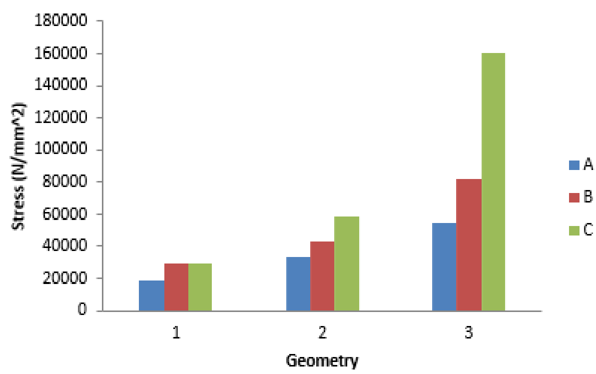


Figure 10. The amount of stress in each geometry

Based on numerical calculations, it was discovered that the safety factor generated by the model was great in the geometry 1 model. Geometry 2 and geometry 3 models showed the similar results as well. Geometry 2 became an alternative replacement for the retaining wall at the Manokwari Landfill, since the geometry model 2 had a better safety factor than the geometry model 3. The other reason was since the geometry model 2 had material properties that adhered with the surrounding environment compared to the geometry model 3.

The force vector produced by each geometry supported the resulting value of the shift and stress distribution. Figure 11 showed the vector of the retaining wall style of all geometries. From the force vector, it was discovered that each geometry got an even force due to the pressure on the ground. When compared from the three geometries, it could be seen that in addition to geometry 1, geometry model 2 was a geometric model that was in accordance with the Manokwari Landfill compared to geometry model 3. This result was strengthened by the direction of the stresses that went to the other side of the stress source was little and had a small strength. This occurred since the geometry model 2 had material properties and a geometric design that was compatible when applied to the geometry model 3. Compared to geometry 3, geometry 2 had a simple geometry and were able to be applied easily. Geometry 3 had a complex geometry that would have taken a lot of time and money to build when compared to geometry 2.

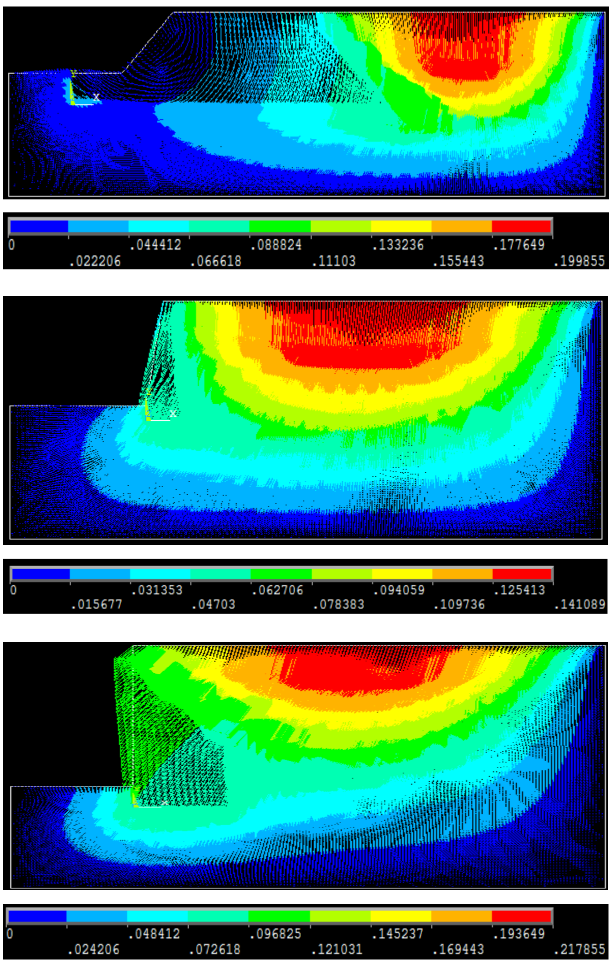


Figure 11. Vector of the retaining wall style of all geometries

4. Conclusions

The numerical method is highly compatible to analyze the compressive strength of the soil retaining wall at the Manokwari landfill site. The results obtained show that model 2 has a higher safety value compared to model 3 even though it has added the number of elements that have to be analyzed. This is also reinforced by the results of the numerical calculations obtained: A2 = 29497.3 N/mm^2, B2 = 42579.2 N/mm^2, and C2 = 82138.8 N/mm^2. This model emerges as another option that is applicable in this area. Besides having a simple geometric shape, model 2 has a higher safety value when compared to the geometry model 3.

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