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Numerical Analysis of Soil-Nailing from Bamboo for Slope Stabilisation Using Plaxis 2D Software

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Abstract: A bare surface of land that has an angle to the horizon is called a slope. This structure of land commonly be subjected to failure when it had a steep slope condition but there are also many causes that lead to its failure. There cases that occur approved that the inclination of the slope is not the only factor that changes its stability. A stable slope can prevent accidents by the public. Slopes are found in hilly areas and some residential areas are built there and many roads are also built through sloping land areas. Lately, there have been a lot of slope collapse problems have occurred, resulting in numerous unwanted incidents which some have cost in deaths of life. Those in charge, on the other hand, have grossly misjudged the problem. Slope areas close to public areas and roads should be investigated for stability so that accidents involving the public do not occur. The main objective of this study is to simulate the different soil movements in the slope before and after the application of the soil-nailing from bamboo using Plaxis 2D and to compare the result of the simulation between 2 types of bamboo soil-nailing which is short (3 meters) and long (4 meters). The properties of bamboo and soil are acquired to use in the Plaxis 2D in order to fulfill the study's goal. After that, a slope modeling in Plaxis 2D and run a simulation with a series of loads; 10kN, 20kN, 40kN, and 45kN. The displayed data are analyzed after the slope's condition has been successfully simulated. The findings of this study indicate that bamboo soil-nailing improves soil stability in terms of safety factors and deformation. The 4m longer bamboo has successfully increased the slope strength, as demonstrated by the comparison with the two types of bamboo soil-nailing. Bamboo has been shown to aid in slope stability, making it a viable alternative to the material currently used in slope stabilizers with a more cost-effective and high-quality product.

Keywords: Bamboo, Soil-Nailing, Stabilization, Plaxis 2D, Roads

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1. Introduction

In this modern era, slope failure has become a major problem in most countries of the world. This is due to the rapid development that is taking place around the world. Slope failure usually occurs due to several factors such as heavy rains or earthquakes that cause excessive loads to be imposed on the top of the slope. Slope failure can cause various problems such as landslides and floods that can affect daily activities, damage properties, and could possibly kill many lives [1]. This study used the new material to strengthen the slope that is different from the current material that is often used which is bamboo. The goal of our study is to produce more economical and quality products to replace current materials such as using bamboo to replace concrete. More than 1400 species of the bamboo family of plants are found in tropical, equatorial, and semitropical biomes throughout the world [2]. Depending on the species and broader ecological conditions, it creates significant and diverse habitats with a variety of specificities. This study creates a simulation using Plaxis 2D software to determine the difference in soil movement on the slope before and after using the slope stabilizer bamboo

This study aims to identify the effectiveness of the slope stabilizer bamboo in overcoming problems such as landslides, and heavy rains that cause the soil to become soft and unstable. According to the background discussion of the study, this study was conducted to achieve the following objective goals: (i) to simulate the different soil movements in the slope before and after application of the slope stabilizer bamboo using Plaxis 2D; and (ii) to compare the simulation data between 2 types of bamboo soil nailing which is a short 3 m bamboo and longer 4 m bamboo models to determine the difference in soil movement on the slope before and after using the slope stabilizer bamboo.

1.1 Bamboo

The material known as bamboo has been around and used for a very long time. Records from more than 7,000 years ago indicate bamboo products including arrows, paper, building supplies, and books [3]. Due to its historical use, current application, and long-term economic viability, bamboo is an excellent resource. Although bamboo may be found growing all throughout the world, with the exception of very cold climates, it is thought to have originated in China. It is where bamboo was first used for common household items. This tall, tough plant was used for as many goods as they could manage because it was a quickly replenishing resource. The bamboo species that are globally recognized evolved from ancient grasses between thirty and forty million years ago [3]. As a result, it became a crucial source of food for herbivorous animals and subsequently became a source of nourishment for modern humans.

1.2 Types of Slope Failure

Fractures, joints, and bedding are the factor that can lead to the mass of rock on the slope to breaks away along the discontinuity plane. The fall is independent of the shear strength of the discontinuity plane that is being reduced by mechanical weathering, propagation, and the existence of water [4]. The separation caused the rock boulder to follow a specific trajectory that is determined by the size and shape of the boulder also the geography of the area is taken into account. The pattern of the falling movement can be free-fall, rolling, bouncing, and a combination of the other pattern.

Next, topples are a type of failure that happens in rocky materials and looks like a fall. This sort of failure, on the other hand, is linked to a rotating motion that happens throughout a specific point in a low area. A combination of gravitational forces and external forces that cause a bending moment such as weathering, water pressure, and freeze-thaw cycles controlled the topple behavior [4].

2. Method and Material

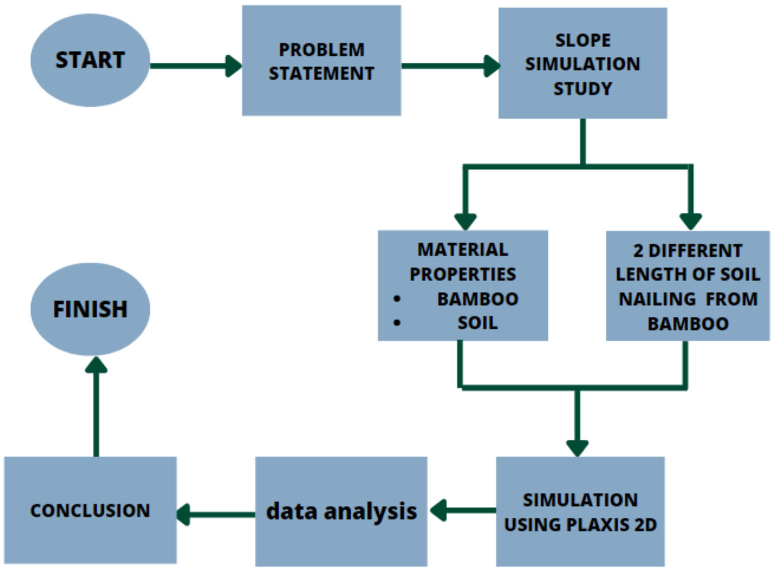

Figure 1: Flow Chart of Methodology

The study was carried out in accordance with the flowchart in **Figure 1**. The procedures used while conducting this research are depicted in the figure.

2.1 Simulation

Slope simulation is very important because the results of the simulation can provide various important information to stabilize the slope. The data that can be produced by this software are soil deformation and safety factors [5][6]. To simulate this slope, 2D Plaxis software is used to obtain the result of slipping on the slope. The slope load, soil strength, and slope angle are determined before starting to build the slope and bamboo soil nailing. This element is very important to simulate so that the type and amount of bamboo that is suitable to be built can be determined. From the results of the slope simulation, the design type of bamboo support that is suitable for the slope can be discovered. Next, the amount of bamboo needed to make the soil nailing can be measured so that it can accommodate the slope. This slope simulation is important in order to produce bamboos that can be used to stabilize the slope over a long period.

2.2 Material and designs

The material used to stabilize this slope is bamboo. Bamboo is a material that is easily available in Malaysia. Bamboo is also a material that is safe to use in the environment, especially on the soil. Based on all types of bamboo available in Malaysia, this study uses Betong bamboo as the material for the soil-nailing. Betong bamboo is lighter than other types of bamboo. Although Betong bamboo is one of the lightest, Betong bamboo is a durable bamboo and slow to rot. Bamboo is also more efficient than logs because bamboo is more readily available than logs.

Table 1: Strengths of some Malaysian bamboos

Species	Compression Parallel to grain (MPa)	Static Bending		
		Modulus of rupture (MPa)	Modulus of elasticity (MPa)	Stress at propotional limit (MPa)
Buluh Duri	19.5 - 28.5	43.1 – 156.4	2.6 – 5.6	21.2 – 38.9
Buluh Minyak	20.5 - 30.0	46.1 – 78.4	4.1 – 8.1	28.7 – 42.6
Buluh Betong	28.3 - 34.6	48.9 – 122.4	3.8 – 8.8	32.2 – 46.8
Buluh Semantan	21.6 - 32.3	35.9 – 68.9	3.7 – 5.9	31.1 – 42.2
Buluh Beting	37.3 - 42.8	37.6 – 119.4	3.7 – 6.5	35.7 – 48.7

The simulation uses data from past study to determine the properties of betong bamboo as shown in the **Table 1**. The data that is taken from this table is the compression data that is 28.3 MPa.

The soil in the slope area is divided into two parts, the upper layer, and the lower layer. The soil in the lower layer has a young's modulus value of 25000 kN/m^2 and the upper layer has a young's modulus value of 15000 kN/m^2. The strength for the lower layer is 8 kN/m^2 and for the upper layer is 4 kN/m^2 [7].

Before bamboo support is plotted in the software, the design is determined to know the stable characteristics to withstand the loads and forces on it. This design is used in this simulation is bamboo soil-nailing. The difference between these two types of bamboo is in the number of bamboo users where one is 3 meters of bamboo as soil nailing and the other is 4 meters of bamboo as soil nailing. The study decided to use this specific length of bamboo because it was also a trial-and-error process where the length was set more than 4 meters failed to simulate in the software. Further studies are needed to find the cause of this problem.

2.3 Analysis of data

The bamboo support model was simulated in Plaxis 2D software with loads of 10 kN, 20 kN, 40 kN, and 45 kN. The deformation and safety factor values are analyzed through Plaxis 2D software, this collected data is turned into a graph to see a clear difference between each simulation. This also determines the relationship between the safety factor and the deformation of the slope. **Figures 2**, **Figure 3 and Figure 4** are illustrating the geometry, safety factor, and soil deformation with different lengths of bamboo soil-nailing and without the bamboo soil-nailing.

The data shown in **Figure 2** is the data of total displacement of the slope soil as a result of no bamboo soil-nailing and applied 10kN of line load. The line load is shown as many blue lines on the slope. The element on the right is the scale of the deformation on the soil. It started from blue with no deformation and red as the highest deformation indicator. It is clear that the deformation is more on the part where the line load is located on the slope. The data that is taken from this figure is the maximum displacement of 0.04837m and the safety factor of 1.278.

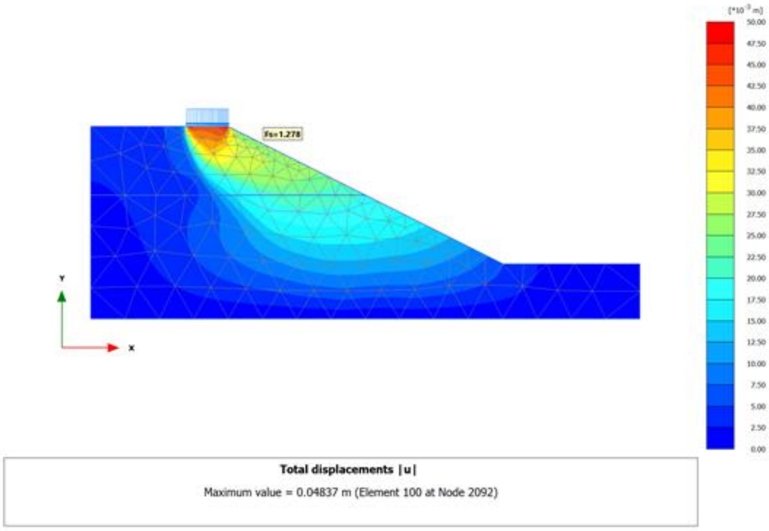

Figure 2: Analysis of slope with no bamboo soil-nailing

The data shown in **Figure 3** is the data of total displacement in the slope soil as a result of the simulation of 4 meters of bamboo soil nailing and applied 10kN of line load. The indicator for the elements is the same as **Figure 2.** The bamboo soil nailing is indicated by the green line. The data that is taken from the figure is the maximum displacement of 0.04782 m. From the simulation, the study also taken the safety factor data that is displayed on the figure that is 1.28.

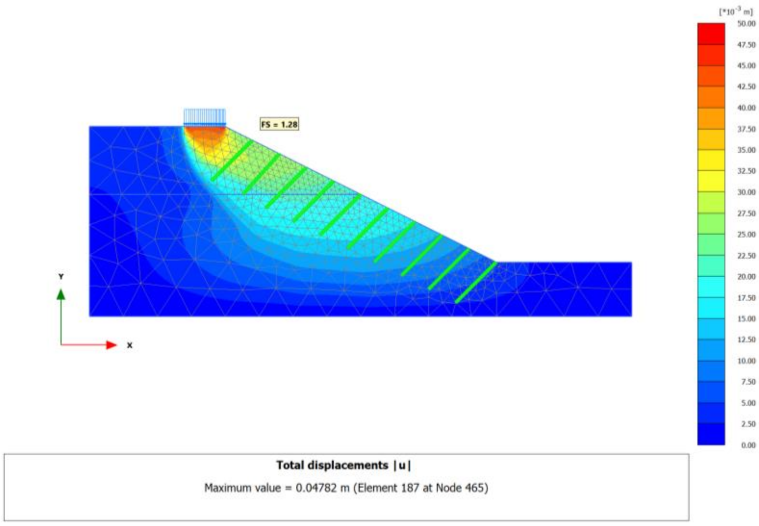

Figure 3: Analysis of longer bamboo soil-nailing

The data shown in **Figure 4** is the data of total displacement in the slope soil as a result of the simulation of 3 meters of bamboo and applied 10kN of line load**.** The indicator for the elements in this figure is also the same as other figures. The data that is taken from this figure is the maximum displacement of 0.05109m and the safety factor of 1.29.

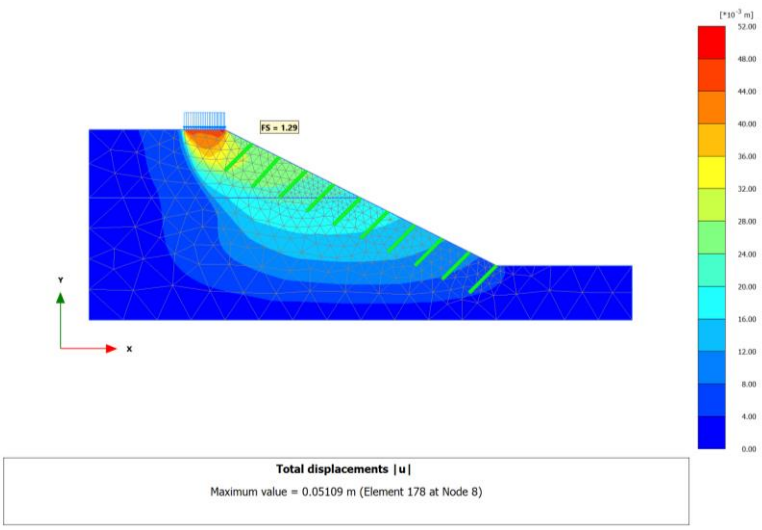

Figure 4: Analysis of short bamboo soil-nailing

3. Results and Discussion

This section summaries the findings from simulation and analysis of the bamboo support model as a slope stabiliser conducted using Plaxis 2D software. The research's findings are presented in numerical form to make them apparent and simple to comprehend.

3.1 Deformation of soil

Figure 5, is the graph data gathered from the simulation of the slope without soil-nailing. This data act as a medium of comparison to the other slope with support. Without loading applied to the slope, the simulation produced 18.32 mm of deformation and a safety factor of 1.343. The lowest load is 10 kN caused 19.18 kN of deformation and had a value of 1.278 for the safety factor. Lastly, the Deformation caused by the highest load is 48.37 and it has a safety factor of 1.026.

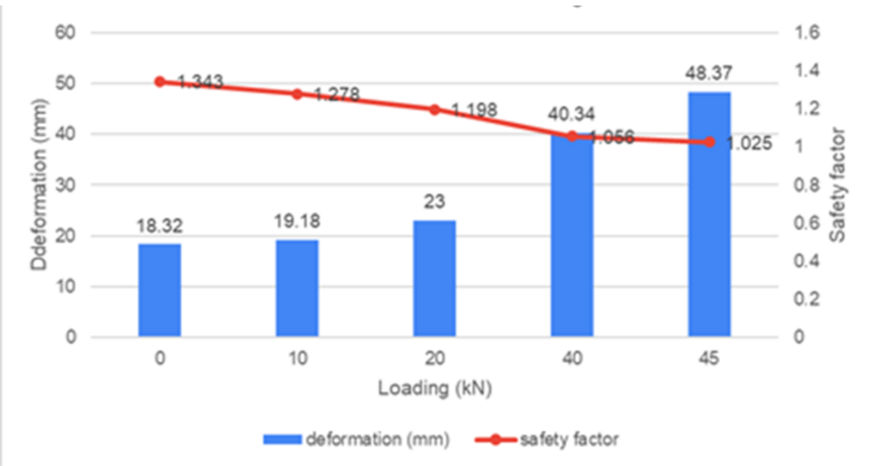

Figure 5: Graph of deformation versus load on the slope without support

Figure 6, is a graph that formed from the data simulation of the long bamboo soil nailing. The data that are gathered are the deformation and highest safety factor for each loading on the slope that has been installed with the long bamboo support. Without any load, the deformation is 19.18mm with a safety factor of 1.37. The lowest load of 10 kN produces a deformation of 19.75 mm and a safety factor of 1.28 while the highest load produces a deformation of 47.82mm and a safety factor of 1.03.

This happen because the long bamboo has a higher surface area compared to short bamboo. So, it can support biggest load compared to short bamboo and safer to be used as soil-nailing slope stabilizer.

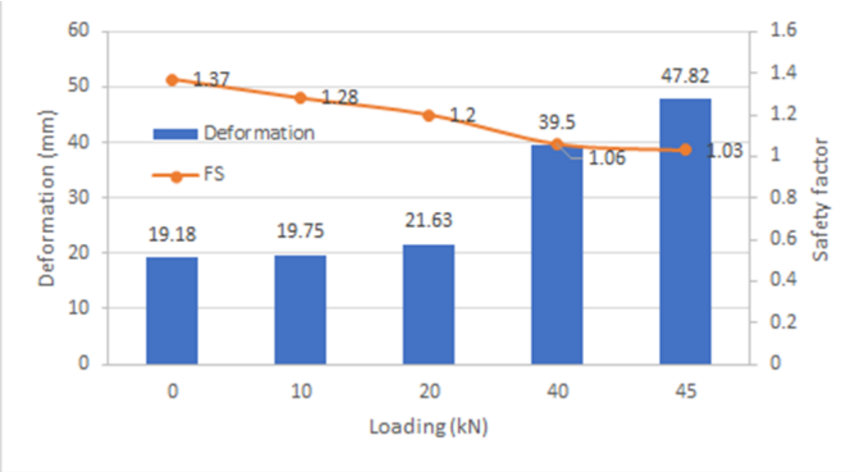

Figure 6: Graph of deformation versus load for long bamboo

Figure 7, a graph that consists of the data from the simulation of short bamboo soil nailing as slope support. The graph shows the deformation and safety factors that had been produced through the simulation. The slope deformation without load is 17.32 mm and the safety factor are 1.378. The deformation and safety factor produced from 1**0**kN of the load is 18.21 mm and 1.29. As for the highest load of 45kN, the deformation is 51.09 mm and the safety factor are 1.03. It shown that short bamboo has a higher peak safety value compare to long bamboo. This happen because short bamboo has lower surface area compared to long bamboo to support the slope.

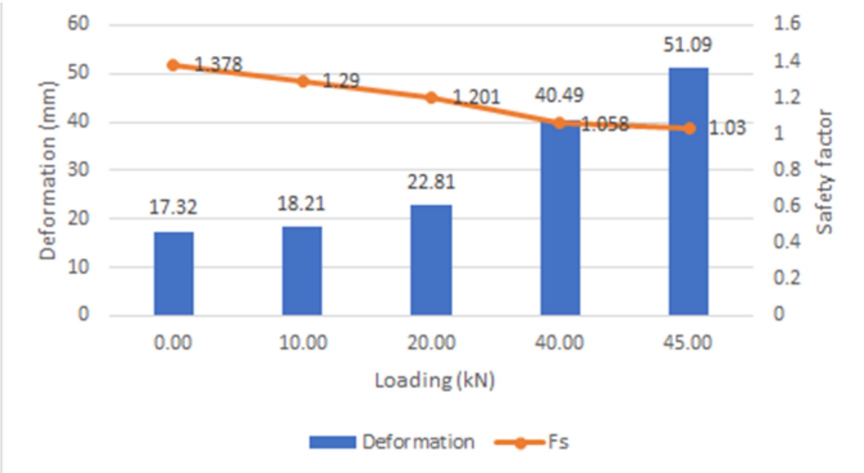

Figure 7: Graph of deformation vs load for short bamboo

3.2 Safety factor

Figure 8 and **Figure 9** represented the graph of safety factors vs steps for long and short bamboo support models. The observation of graphs from Figures 3 and 4, observed that even though the longer bamboo support has a higher safety factor, the shorter bamboo support has more consistency through the steps. The longer bamboo support has a few sudden drops in safety factors at a certain point of the steps. This may happen due to crack or high bending on the bamboo at certain force applied. It shows that the long bamboo support still needs to be improved in order to withstand a higher load constantly.

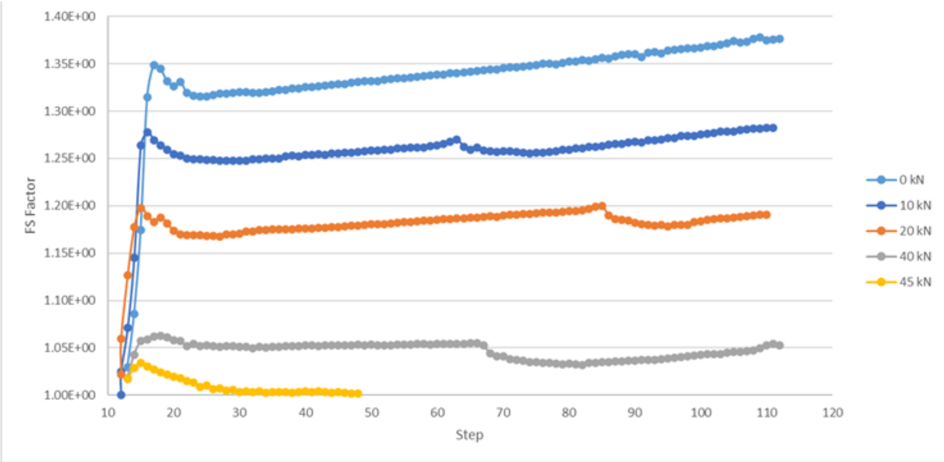

Figure 8: Graph of safety factor vs step for long bamboo support model.

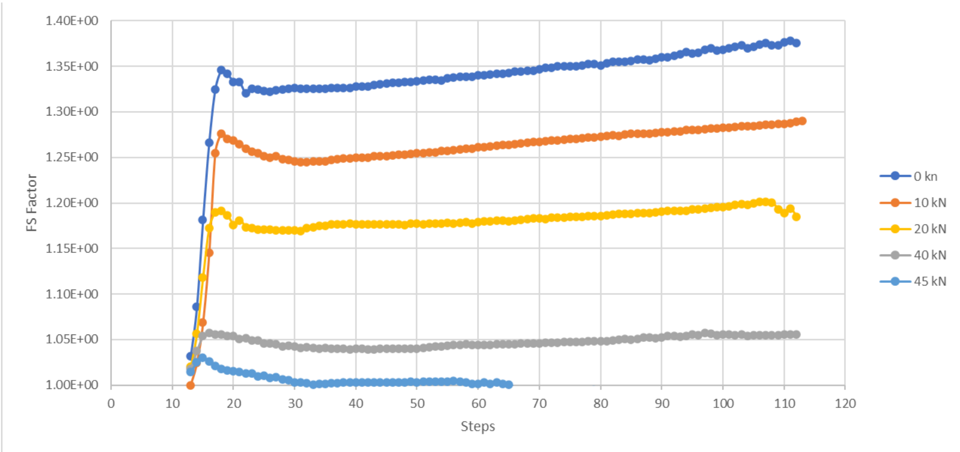

Figure 9: Graph of safety factor vs step for short bamboo support model.

3.3 Summary

Based on **Figure 10**, shows the graph summary of the analysis comparison between the long and short bamboo support model. Based on all the data that have been collected, it shows that the safety factor is inversely proportional to the deformation of the slope. This is because the deformation can cause the slope to become unstable. Based on the data obtained, at the highest load value, the long bamboo support model has a lower deformation value which is 47.82 mm compared to the short bamboo support model which is 51.09 mm. This data is also in the range of previous research which has the range of 40 to 50 mm of deformation value at the end phase that is counted by days [8].

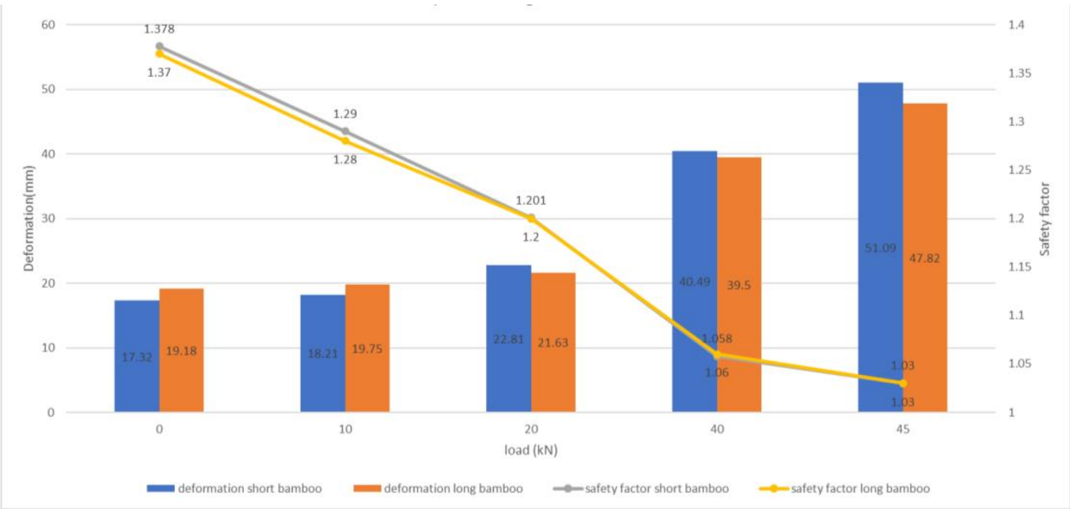

Figure 10: Graph summary of the analysis comparison between the long and short bamboo support model.

Comparing these two data shows that the longer bamboo is proven to be more suitable to be the support for the slope. The deformation data also shows that the slope can maintain its shape more effectively when using the long bamboo support. Comparing the safety factor of the two supports, this study concludes that the longer bamboo support model is safer to be used as a slope stabilizer. With only a slight difference in the safety factor, the long bamboo shows that it had more room for improvement. The longer bamboo support can reach more surface underground to help strengthen the soil but the data show that there is a sudden decrease in safety factors. This may cause by the bamboo bending or crack in the bamboo because of its length. So, some improvement to increase the slope stabilizer need to be make before the bamboo stabilizer being use in the real-life situation.

4. Conclusion and Recommendation

Based on the study was conducted by testing 2 types of bamboo support as slope stabilizers. The first model is a slope fitted with short bamboo supports. The second model is a slope fitted with long bamboo supports. The first objective of this study was to find the value of soil deformation and safety factors before and after the bamboo are attached. This objective has been achieved as shown in chapter 4. The design of the installed bamboo is suitable for the slope conditions. The second objective of this study is to obtain the difference in simulation results between the 2 types of slope support. This objective is achieved as the study is able to make a comparison between the different soil movements in the slopes that are simulated. As a result of the Plaxis 2D simulation, the soil deformation value and the safety values are obtained. From this value obtained, the study was able to distinguish soil deformation and safety factors before and after the bamboo support models were installed. The soil deformation value obtained from the simulation results shows the soil deformation value decreased after the bamboo was installed. While the value of the safety factor also increased after the bamboo was installed. Then for the long bamboo supports, the value of soil deformation is declining. The safety factor value is also increasing.

There are some suggestions about how to enhance this study better in the future. First, researchers should continue this research by looking into ways to plot a more complicated and better type of bamboo slope support model other than a soil nailing technique, in order to encourage the development of better slope stabilizer with lower cost but higher quality to replace the already used materials, slope stabilizer provision can be enhanced from time to time. Secondly, the researchers can study to use many different types of slopes and add water flow to the study when performing simulations on the bamboo slope models to ensure the strength of the bamboo as a slope stabilizer. As a result, an authentic source can support the study's findings and data.

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