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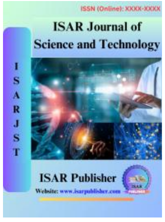

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PEAT SOIL IMPROVEMENT DESIGN ANALYSIS USING GEOGRID

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Abstract: Peat soil is a mixture of organic fragments originating from vegetation that has chemically turned into fossils. Peat soil is included in a broader category of soil called organic soil, which is soil that has a significant organic content that affects the geotechnical properties of the soil. Peat is organic soil with a high organic content. Because of the soft nature of peat soil, reinforcement is carried out using Biaxial Geogrid. From the model research in the laboratory, the results showed that with the addition of the number of reinforcement layers and the effective depth distance of the layers, it would provide a greater BCR (Bearing Capacity Ratio) value. After testing the variation of reinforcement sizes 2B, 3B and 4B with a layer depth of d = 0.25B; d = 0.5B; and d = 1B with the number of layers 1 layer, 2 layers and 3 layers with 2 types of geogrid reinforcement, the combination that provided the highest bearing capacity value was the use of a variation of reinforcement size 4B with a layer depth of d = 1B with a number of layers 3 layers with Biaxial Geogrid reinforcement. The bearing capacity value is 13.6076 kPa with a BCR value of 3.704 or an increase of 270.370%.

Keywords: Soil Improvement, Peat, Bearing Capacity Ratio (BCR), Geogrid, Ogan Komering Ilir Regency (OKI).

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1. Introduction

Peat soil is a soil formed from the accumulation of incompletely decomposed organic matter, has an organic matter content of more than 75% and a minimum thickness of around 30-50 cm. This soil is highly compressible, has low bearing capacity, and highwater content, making it challenging for civil engineering purposes (Huat et al, 2014). The characteristics of peat soil include having a very high's water content and compressibility, a distinctive color of dark brown to blackish. This layer of soil is found around tropical forests and lowlands with abundant and humid waterlogging factors and relatively less air heat (Zulkifley et al, 2013). Venmans (1995), to classify the peat soil parameters based on organic content (loss on ignition), natural water content, shear strength, and Von Post test for humification level.

Peat soil is a type of soft soil with poor geotechnical characteristics such as low bearing capacity, long-term consolidation, and large potential for land subsidence. This condition causes various challenges in the construction of infrastructure such as roads, buildings, and embankments on peat soil. To overcome these weaknesses, soil reinforcement technology using geogrids has been widely used and researched. Geogrids are geosynthetic materials that function to strengthen the soil through interlocking mechanisms and lateral stress distribution. Its application has been proven to increase stability, reduce subsidence, and accelerate the consolidation process on peat soil.

Several important studies have shown the success of using geogrid method are geogrids can significantly increase the strength of peat soil and reduce deformation of structures above it (Rowe and Mylleville, 1996). The use of geogrids in road and embankment foundation systems on peat soils has shown satisfactory performance in reducing settlement and increasing bearing capacity, especially when combined with stone columns or deep foundations (Han and Akins, 2002), (Black and Sivakumar, 2005). The application of geogrids in real projects such as road construction in Sumatra and Washington, USA has shown cost efficiency and increased stability without the need to replace the entire soft soil layer (Barry et al, 1995), (Blackwood and Vulova, 2006). Numerical analysis shows that the use of geogrids in combination with sand columns or stone columns significantly strengthens the structure by reducing land settlement (Mujah et al, 2016).

The use of biaxial geogrids significantly increases the resilient modulus of soil, especially when used in multiple layers at a certain depth. This helps to seamlessly connect hard structures (such as bridge abutments) to soft subgrades (You-chang, 2008).

Studies using poor quality subgrades reinforced with biaxial polyester geogrids showed significant increases in CBR values (36-41%) and unconfined compressive strength (62-70%). Interlocking and friction between the soil and geogrid fibers are considered to be the main factors for this increase (Mittal and Shukla, 2019).

Experimental studies have shown that biaxial geogrids have better reinforcement characteristics than uniaxial geogrids in terms of shear interaction and interlocking force in various types of soils, especially soft or high-moisture soils (Hui, 2009). Discrete element simulations show that biaxial geogrids provide strong interlocking effects in soft granular materials. These simulations are very useful for understanding the behavior of geogrids in reinforcing peat soils or other types of compressible soils (Stahl et al., 2014).

2. Literature Review

Peat is a mixture of organic material fragments originating from plants that have changed their properties chemically and become fossils. Peat material that is below the surface has a high compressibility compared to general soil material. Peat soil has different physical properties from other types of soil. Several studies have shown that the physical properties of peat soil are low (large pore number, high water content and low soil volume weight), especially peat soil is non-cohesion soil. According to Mac Farlane, based on the fiber content, peat soil can be classified into:

1. Fibrous Peat, is peat soil that has a fiber content of 20% or more, and this peat has two types of pores, namely macropores (pores between fibers) and micropores (pores in the fibers concerned). Fibrous peat has a very different behavior from clay soil due to the presence of fibers in the soil.
2. Amorphous Granular Peat, is peat that has a fiber content of less than 20% and consists of grains with a colloidal size (2µ), and most of its pore water is absorbed around the surface of the peat grains. Due to these conditions, this type of peat soil has properties that resemble clay soil.

Geogrid is a geosynthetic material forming a set of intersecting ribs and connected in parallel with holes sufficient to allow the surrounding soil, rock, or other geotechnical materials to pass through. According to ASTM D4439-02 (2003), geogrid is a geosynthetic formed by a regular network of integrally connected elements with holes larger than 6.35 mm (¼ inch) to allow interlocking with the surrounding soil, rock, and other surrounding materials with the primary function as reinforcement.

The following are the types of geogrids:

1. Geogrid Uniaxial (Figure 1), having high strength in the longitudinal direction only, this Geogrid is used to strengthen embankments, slopes, retaining walls.

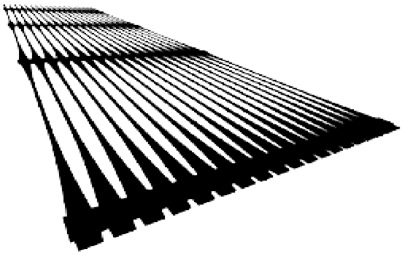

Figure 1 : Uniaxial Geogrid Shape

2. Geogrid Biaxial (Figure 2), has strength in both directions, both longitudinally and transversely. This geogrid is used to stabilize roads without pavement or pavement, and also on railways.

Figure 2 : Biaxial Geogrid Shape

3. Geogrid Triax (Figure 3), has strength from various directions, the use of this geogrid is the same as the biaxial geogrid, only this geogrid provides more uniform tensile strength than the biaxial geogrid.

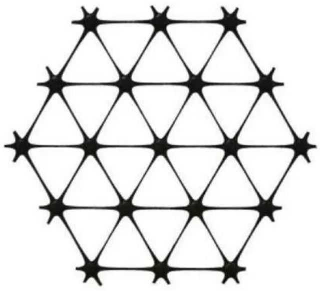

Figure 3 : Triax Geogrid Shape

3. Methods and Materials

The method using in this research was laboratory work consists of testing index properties and testing mechanical properties. This index properties test consists of two tests, namely physical properties testing and chemical properties testing. Before conducting the Triaxial test, first the undisturbed peat soil sample in the tube is prepared. The soil sample must be molded in the tube so that the soil sample is completely undisturbed. The soil sample must be removed in the same direction as the direction when the soil sample was taken in the field, with one uniform extruder movement.

This research uses biaxial geogrids for improving peat soil. Testing is carried out after the peat soil is soaked until saturated and the water content approaches the original value in the field.

Furthermore, testing is carried out on modeling with variations in the width of reinforcement (2B, 3B, 4B) for single reinforcement (1 layer). Further testing is carried out with variations of 2 layers of reinforcement and 3 layers of reinforcement at each width of reinforcement (2B, 3B, 4B), with a distance between reinforcements of 0.5B with B being the width of the foundation model and sand as the backfill. For testing with variations in the width of reinforcement against the number of layers of reinforcement, one test is carried out for each variation (Aazokhi, 2014). Before testing is carried out, the soil in the test tank is excavated to a depth of 0.5B (7.5 cm) with a width according to the variations that have been determined in each test. After excavation, the reinforcement variations are inserted into the excavation with a geogrid arrangement first.

The excavation is filled with sand. After preparing the test object, the load retainer is then installed. Then the foundation modeling is installed in the form of a plate measuring 15cm x 15cm x 2cm, load cell, jack, and LVDT. Modeling for this test will be carried out in 9 variations, namely variations in the number of reinforcement layers and variations in the height difference d (d) is the distance between the ground surface and the first soil reinforcement layer (ASTM D-1196-93., 1993). Modeling is shown in Figure 5. And the number of samples in the test tub test is shown in Figure 4.

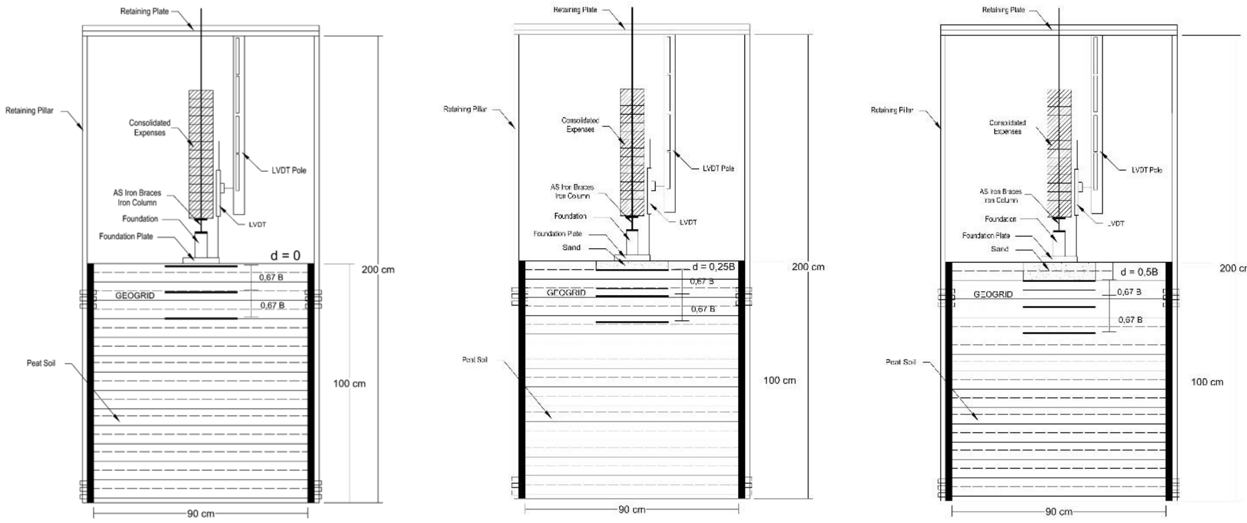

Figure 4: Sketch of the Test Model for Plate Load Test on Peat Soil

4. Results and Discussion

Index Properties and Mechanical Properties of Peat Soil

Testing of physical properties of the soil is testing the characteristics of the original soil in the form of peat soil. The soil from this test was obtained from Parit Village and Lorok Village, Ogan Komering Ilir Regency, South Sumatra Province. The tests carried out include water content tests, Specific gravity tests, fiber content tests, organic content tests, ash content tests, and acidity levels (pH) tests. Data from the results of testing the physical properties of the original soil can be seen in table 1 below.

Table 1: Summary of peat soil laboratory test results

Table 1: Summary of peat soil laboratory test results

	Result
Index Properties	
Specific gravity	1.53
pH	3.50
Ash Content (AC, %)	32.91
Organic Content (OC, %)	67.09
Fiber Content (FC, %)	24.96
Water Content (w) (%)	357.36
Mechanical Properties: Triaxial Compression Test (UU)	
Angel of Internal Friction (ϕ) (^{o})	1.35
Cohesion (c) (kg/cm^2)	0.05

Soil Bearing Capacity Test Results

The magnitude of the ultimate bearing capacity value due to variations in layer depth and number of layers in peat soil reinforcement using biaxial geogrids is explained in Table 2 below:

Table 2: Recapitulation of the ultimate bearing capacity values of peat soil

Reinforcement Type	Reinforcement Size		Variation d	Number of Layers	Bearing Capacity (kPa)
Biaxial	2B	(30x30 cm)	0.25B (3.75 cm)	1 Layer	5.579
				2 Layer	6.058
				3 Layer	6.233
			0.5B (7.5 cm)	1 Layer	5.906
				2 Layer	6.363
				3 Layer	6.669
			1B (15 cm)	1 Layer	6.276
				2 Layer	6.734
				3 Layer	7.061
Biaxial	3B	(45x45 cm)	0.25B (3.75 cm)	1 Layer	5.666
				2 Layer	6.363
				3 Layer	6.538
			0.5B (7.5 cm)	1 Layer	6.233
				2 Layer	6.647
				3 Layer	6.886
			1B (15 cm)	1 Layer	6.581
				2 Layer	7.061
				3 Layer	7.279
Biaxial	4B	(60x60 cm)	0.25B (3.75 cm)	1 Layer	6.037
				2 Layer	6.886
				3 Layer	6.986
			0.5B (7.5 cm)	1 Layer	6.625
				2 Layer	7.257
				3 Layer	7.279
			1B (15 cm)	1 Layer	6.974
				2 Layer	7.802
				3 Layer	7.627

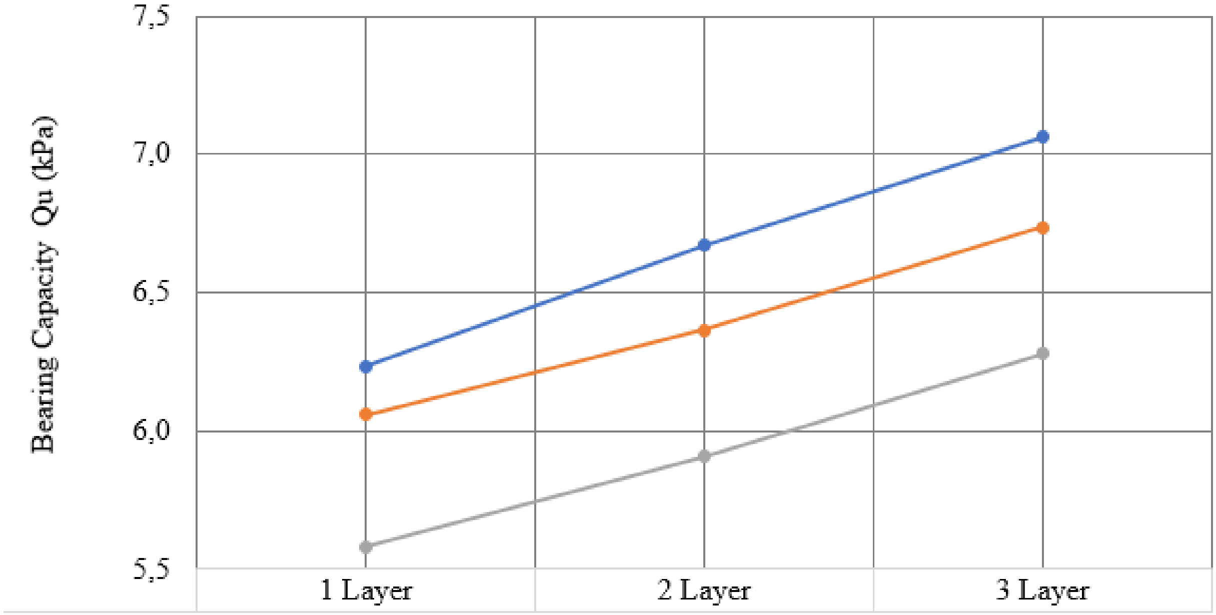

Figure 5: Graph of the increase in the ultimate bearing capacity value of the Biaxial Geogrid 2B reinforcement (30x30 cm)

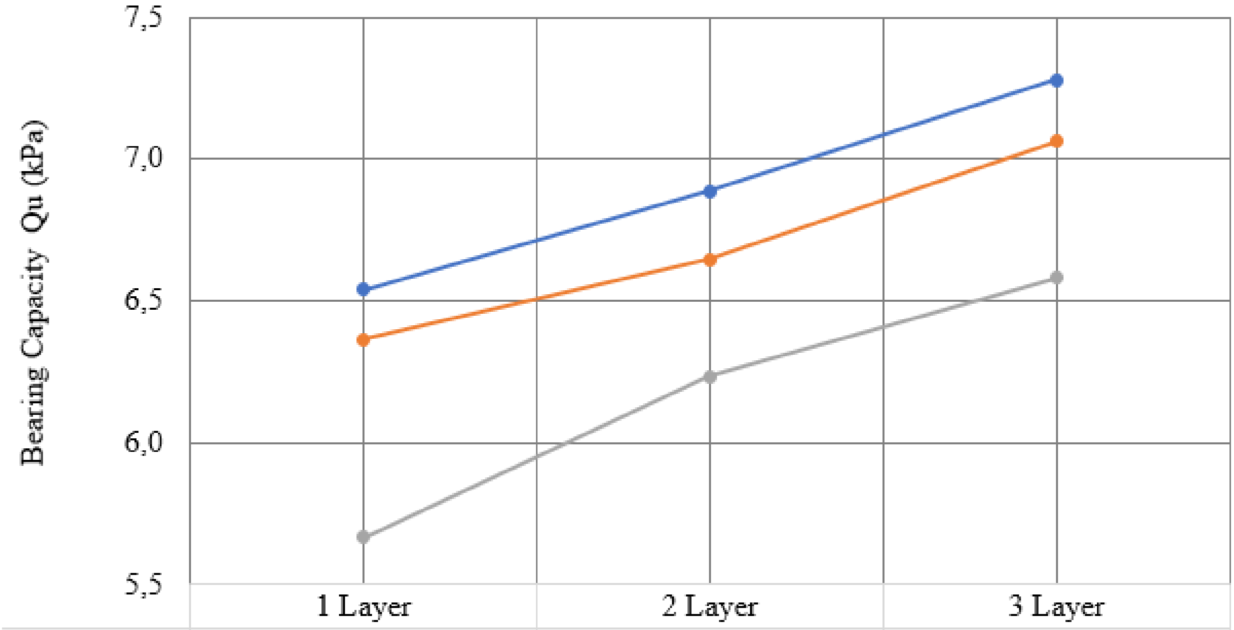

Figure 6: Graph of the increase in the ultimate bearing capacity value of the 3B Biaxial Geogrid reinforcement (45x45 cm)

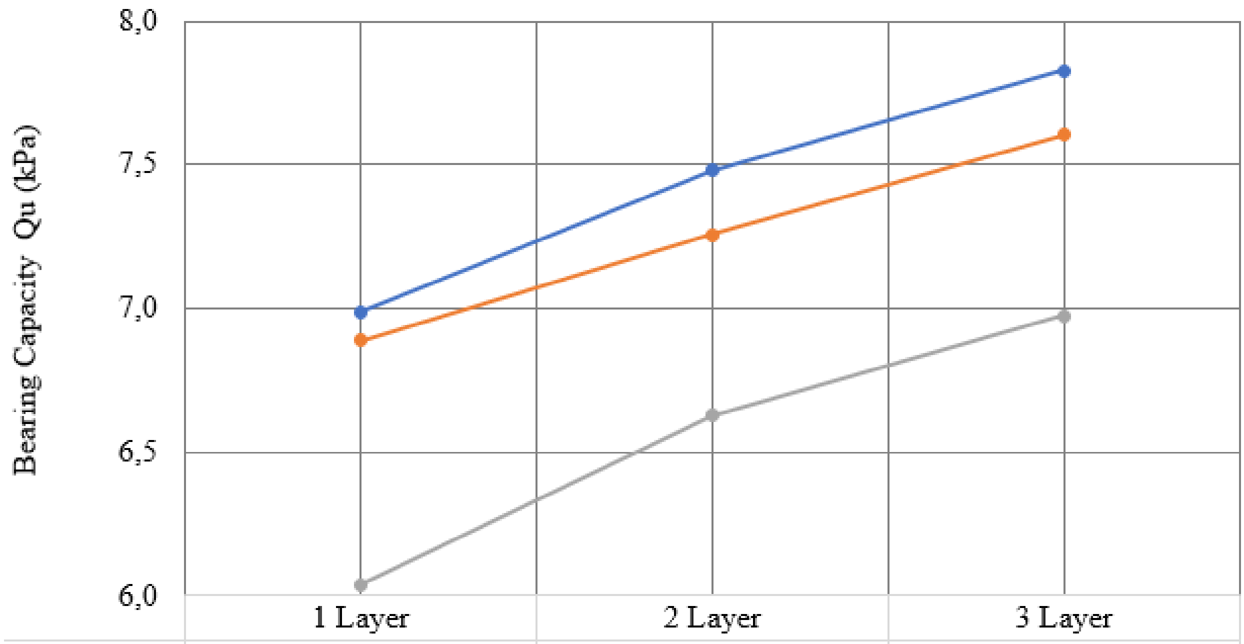

Figure 7: Graph of the increase in the ultimate bearing capacity value of the 4B Biaxial Geogrid reinforcement (60x60 cm)

As explained in Figure 5 to Figure 7 on the test sample with all variations of layer depth and variations in the number of reinforcements of 1 layer, 2 layers, and 3 layers, it provides an increase in the bearing capacity of each test sample. Based on the results of the bearing capacity, it can be said that at each layer depth with a greater number of reinforcement layers, it will provide greater bearing capacity. From the two reinforcements used, the results of the bearing capacity with triax geogrid reinforcement were greater than the reinforcement using biaxial, this is because the tirax geogrid is a development of the biaxial geogrid with triangular cavity openings, and has better performance than biaxial because the arrangement of its triangular cavities is stiffer, so that the load distribution becomes more even and its interlocking ability is stronger.

BCR Value (Bearing Capacity Ratio)

The magnitude of the BCR value due to variations in layer depth and number of layers in peat soil reinforcement using biaxial geogrids is explained in Table 3. Analysis of BCR value and BCR increase percentage based on reinforcement without the use of Biaxial Geogrid and with the use of Biaxial Geogrid.

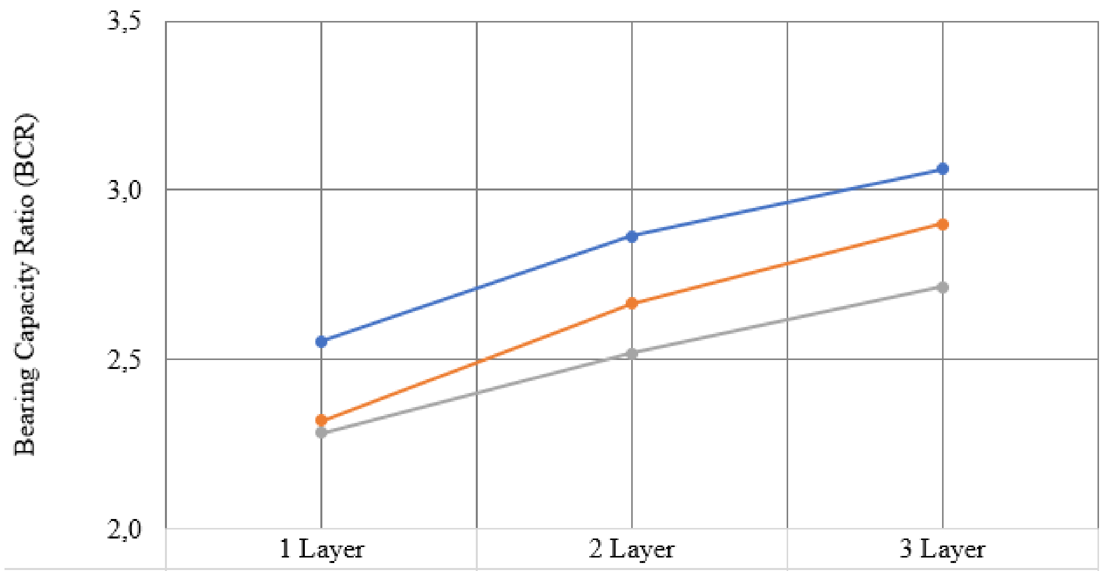

Figure 8 : Graph of the increase in BCR value of Biaxial Geogrid 2B reinforcement (30x30 cm)

Table 3: Recapitulation of BCR Calculation and Percentage of BCR Increase with Biaxial Geogrid Reinforcement

Reinforcement Type	Reinforcement Size	Variation d	Number of Layers	Q_u (kPa)	q_u (kPa)	BCR	% BCR Increase
Without Reinforcement	-	-	-	-	3.530	1	-
Biaxial	2B (30x30 cm)	0.25B (3.75 cm)	1 Layer	5.579	-	1.002	0.196
			2 Layer	6.058	-	1.088	8.806
			3 Layer	6.233	-	1.119	11.937
		0.5B (7.5 cm)	1 Layer	5.906	-	1.018	1.761
			2 Layer	6.363	-	1.143	14.286
			3 Layer	6.669	-	1.198	19.765
		1B (15 cm)	1 Layer	6.276	-	1.084	8.415
			2 Layer	6.734	-	1.209	20.939
			3 Layer	7.061	-	1.268	26.810
	3B (45x45 cm)	0.25B (3.75 cm)	1 Layer	5.666	-	1.061	6.066
			2 Layer	6.363	-	1.143	14.286
			3 Layer	6.538	-	1.174	17.417
		0.5B (7.5 cm)	1 Layer	6.233	-	1.119	11.937
			2 Layer	6.647	-	1.194	19.374
			3 Layer	6.886	-	1.237	23.679
		1B (15 cm)	1 Layer	6.581	-	1.190	18.982
			2 Layer	7.061	-	1.268	26.810
			3 Layer	7.279	-	1.307	30.724
	4B (60x60 cm)	0.25B (3.75 cm)	1 Layer	6.037	-	1.127	12.720
			2 Layer	6.886	-	1.237	23.679
			3 Layer	6.886	-	1.237	23.679
		0.5B (7.5 cm)	1 Layer	6.625	-	1.127	12.720
			2 Layer	7.257	-	1.303	30.333
			3 Layer	7.279	-	1.307	30.724
		1B (15 cm)	1 Layer	6.974	-	1.252	25.245
			2 Layer	7.802	-	1.401	40.117
			3 Layer	7.627	-	1.370	36.986

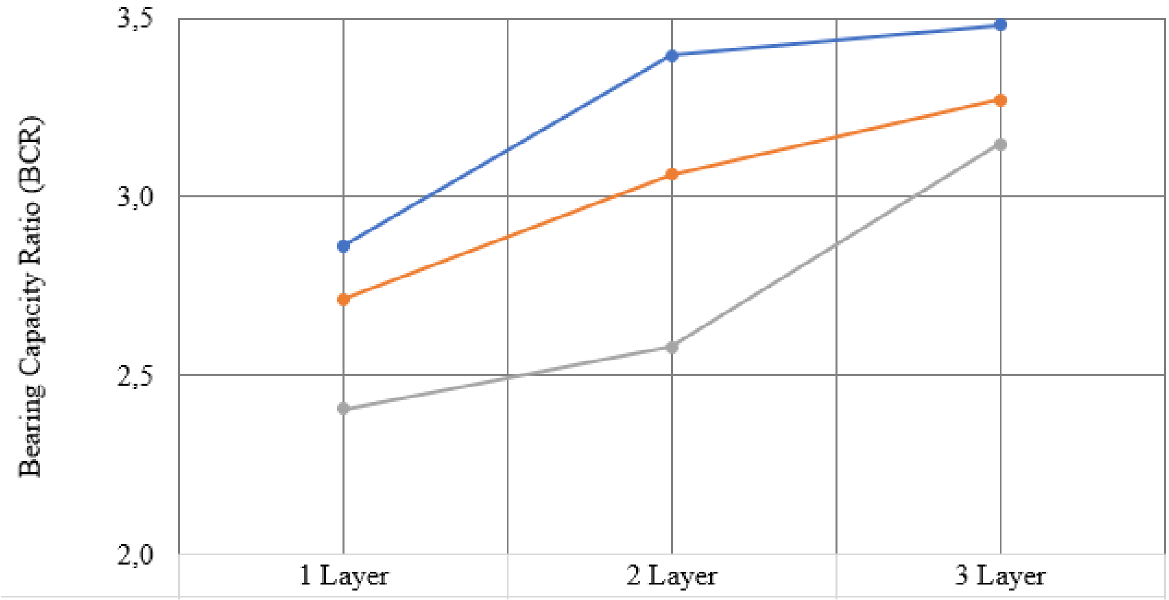

Figure 9 : Graph of the increase in BCR value of Biaxial Geogrid 3B reinforcement (45x45 cm)

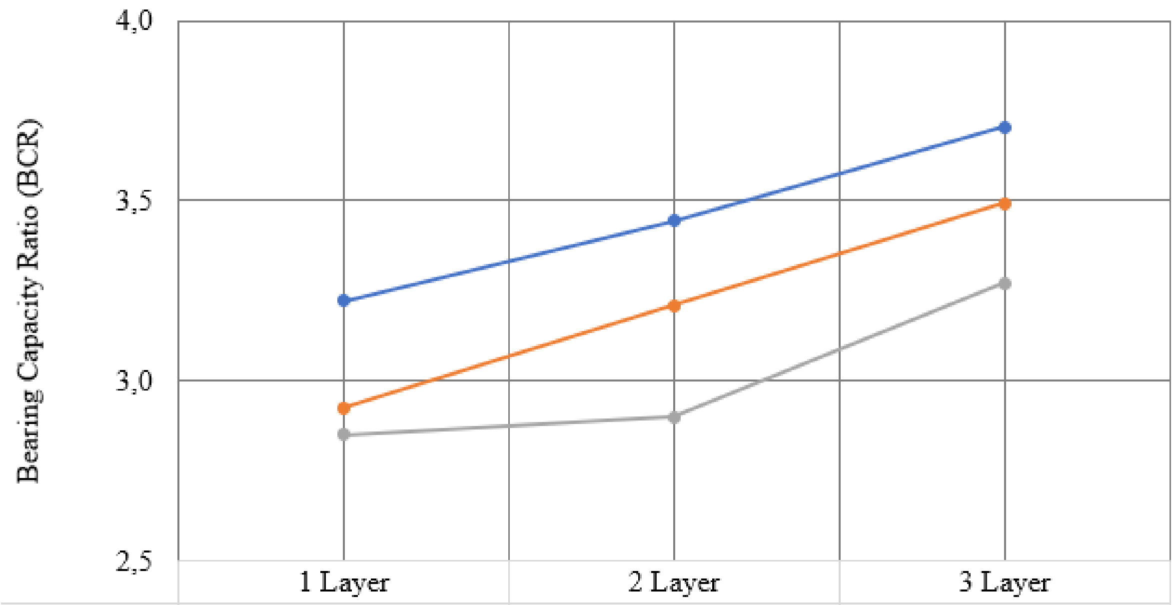

Figure 10 : Graph of the increase in BCR value of Biaxial Geogrid 4B reinforcement (60x60 cm)

From Figure 8 to Figure 10 above, it can be concluded that the bearing capacity ratio (BCR) value will always increase along with the increasing number of layers. This is because in a soil reinforcement, the combination of soil and reinforcement must be such that the interaction between the two produces a combined material with much better behavior. Soil that generally has good compressive strength and very weak tensile strength can be improved by adding reinforcement that has tensile strength. The cooperation between these two materials provides interconnected materials and improves the behavior of the original soil. The more layers of reinforcement used, the faster the soil will be held back by the many layers of reinforcement installed underneath.

5. Conclusion

Based on the results of the bearing capacity test, it was found that at each layer depth with a greater number of reinforcement layers, the bearing capacity would be greater. The bearing capacity ratio (BCR) value will always increase with the increasing number of layers. This is because in soil reinforcement, the combination of soil and reinforcement must be such that the interaction between the two produces a combined material with much better behavior. Soil that generally has good compressive strength and very weak tensile strength can have its behavior improved by adding reinforcement that has tensile strength. The cooperation between these materials provides interconnected materials and improves the behavior of the original soil. The more layers of reinforcement used, the faster the soil will be held back by the many layers of reinforcement installed underneath.

The use of geogrids as a peat soil improvement solution has proven effective in increasing stability, reducing subsidence, and enabling safe and sustainable infrastructure development on land previously considered problematic. And reinforcement with biaxial geogrids has been proven effective in increasing the strength and stability of peat soil or similar soft soil, both through laboratory tests and numerical modeling, especially due to the interlocking ability and more even stress distribution.

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