International Journal of Advanced Science and Computer Applications (2024); 3(1): 65-74
DOI: 10.47679/ijasca.v3i1.47
https://ijasca.org/index.php/ijasca

RESEARCH ARTICLE

Characteristic behavior of soil using bacterial biogrouting with LISA FEA V.8.

Aco Wahyudi Efendi [1]

Published online: 20 November 2023

Abstract

The increasingly widespread use of micro-bacteria in research to improve soil characteris-tics in the world of construction and also provide a significant increase in soil carrying ca-pacity so that this kind of research makes a very good contribution where the material and mixing object are natural materials, namely in the form of bacteria. This study used the finite element method with the help of LISA V.8 FEA (Li-cense), a finite element method software package, to obtain the stress arising from existing soil ma-terial with soil material that has been mixed with mycobac-teria or the biogrouting method. According from the results of the analysis using numerical analysis using the finite el-ement method LISA V.8 FEA program, it can be seen that there is a reduc-tion in the oc-currence of settlement after adding the two bacteria which have been aged for 30 days with a reduction in soil settlement of 2.9-2.27 mm de-spite an increase in stress. ranging from 58.3 to 69.4 kN/m^2.

Keyword: Bacterial, Biogrouting, FEM, LISA, Soil, Stress

Introduction

The increasingly widespread use of micro-bacteria in research to improve soil characteristics in the world of construction and also provide a significant increase in soil carrying capacity so that this kind of research makes a very good contribution where the material and mixing object are natural materials, namely in the form of bacteria.

Bacteria Bacillus subtilis and Pseudomonas sp can increase the value of shear strength, besides that these two bacteria can reduce the value of soil permeability (IFFAH FADLIAH, 2013; Jack W et al., 2022; Mahawish et al., 2016; Muhammad Saleh Nasution et al., 2017; NANDA AFIANDA, 2022; Wu et al., 2019; Wu & Chu, 2020). The grouting method of stabilizing sandy loam soil can boost the soil's carrying capacity by incorporating microbes. This is demonstrated by the soil's increased strength and decreased seepage (IFFAH FADLIAH, 2013).

This study used the finite element method with the help of LISA V.8 FEA (License), a finite element method software package, to obtain the stress arising from existing soil material with soil material that has been mixed with mycobacteria or the biogrouting method.(Hoehler et al., 2017).

Methods

The addition of a solution of Bacillus subtilis bacteria, which was injected into the soil sample, was tested for its mechanical properties (free compressive strength, permeability, and direct shear), four times, with a 28-day curing period. In comparison to the compressive strength value without bacteria, the results of the free compressive strength test showed a 60% increase in compressive strength. The value of the permeability coefficient decreases in soil that has been stabilized by bacteria. The cohesiveness value is increased by adding more bacteria to the soil sample via direct shear testing (c) (IFFAH FADLIAH, 2013).

A peat soil sample used in the study had a specific gravity of 1.53, a moisture content of 351.092%, an optimal moisture content (OMC) of 132%, and a maximum dry density value (d max) of 0.40 gr/cm3. Native peat soil had the greatest CBR value, at 0.76% after 4 days of ripening. After stabilization with the combination, the addition of 5% bacterial reagent with a 0.76% cure duration of 4 days had the highest CBR value. The results of the research indicate that the bacterial reagent bacillus subtilis cannot be added to peat soil to

[1] Postgraduate Study Program UNS S3 (Doctoral) Degree in Civil Engineering. Kentingan, Jl. Ir Sutami No.36, Kec. Jebres, Kota Surakarta, Jawa Tengah 57126

*) corresponding author

Aco Wahyudi Efendi

Email: acowahyudiefendi@student.uns.ac.id

improve it; nevertheless, it can be applied along with other mixed components (NANDA AFIANDA, 2022).

Generally speaking, there are two methods for stabilizing soil: mechanically and chemically. By using mechanical soil stabilization, the requisite standards can be met with well-graded soil. The goal of mechanical soil stabilization is to improve the gradation of the soil grains in question in order to increase density, add, and mix the existing soil (natural soil) with other types of soil to create a new, better gradation. This will increase the strength and carrying capacity of the soil. examples of soil stabilization through mechanical means. The gradation of soil grains with a chemical potential for binding (binder soil) and water content need to be taken into account while mechanical soil stabilization is being done.

If the original soil used as the basis of a road pavement has a poor quality of carrying capacity to be employed as a subgrade or as embankment material, soil stabilization must be done right away.

The subgrade will greatly influence the thickness of the overlying pavement layer, the physical characteristics of the pavement in the future, and the behavior of the pavement, such as surface deformation and other factors, so it is important to choose the best type of soil that can be used as subgrade through soil investigation. Road construction frequently runs into the issue of inadequate strength (resistance to deformation), which can result in accidents or financial losses.

A solution to this issue is subgrade soil improvement combined with stability. In order to make the current soil's qualities fulfill technical requirements, stabilizing the subgrade is a necessary step in road construction. These characteristics are anticipated to be met by the pavement layers in road pavement structural systems.

Biogrouting

Construction material called grout typically contains of a cement and sand mixture This substance might be utilized for because these minerals are deposited, the soil's structure will be improved. alter the soil's geomorphological characteristics. Typically, silica compounds are mixed chemically to create grout for engineering or other reasons (waterglass). When combined with metal solutions or bicarboxylic acids, silica quickly precipitates. Due to the low permeability and high injection pressure required by this method, the soil may become unstable. Through the mechanism of calcium carbonate deposition, a biological grouting technology known as bio-grouting technology has been developed recently.

The fundamental benefit of biogrouting is the ability to transmit the applied substrate in an inert state to locations remote from the injection source. Technology known as "biogrouting" imitates the diagenesis process, which sees sand grains turn into sandstone (calcarenite or sandstone). Sandstone will be created when calcium carbonate crystals connected by biogrouting technology act as a cementing agent between sand grains. It is only natural that this process could take millions of years. Therefore, by leveraging the carbonate precipitation process brought on by bacterial metabolic activity and shown in Figure 1, bacteria are used to speed up the synthesis of calcite.

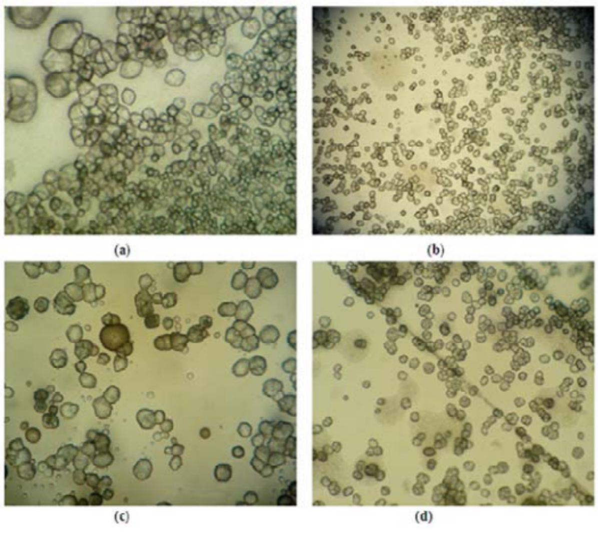

Figure 1. A variety of calcite crystal forms produced by bacterial urease enzyme biogrouting (20x). (Lisdiyanti, 2011).

The ability of bacteria to endure and be tolerant of high concentrations of urea and calcium is directly tied to their participation in the biogrouting process. Additionally, these bacteria must be able to create very active urease enzymes. Due to the high urea concentration in the biogrouting procedure, it is hydrolyzed during cementation. Therefore, the only bacteria that can be used are those whose urease enzyme activity is not inhibited by ammonium. Because they have strong urease activity and are not harmful, bacteria from the genus Sporosarcina (Bacillus) have started to be used in the biogrouting process at this time (IFFAH FADLIAH, 2013).

Mycobacteria

Bacillus subtillis is a catalase-positive bacteria that is frequently found in soil. A thermophilic bacterial species known as Bacillus subtlis can thrive at temperatures between 60 and 80 degrees Celsius.

Pseudomonas sp. has straight rod-shaped cells, albeit they can occasionally take on a rounded shape. Colony diameter: between 0.5 and 0.8 mm. Hydrocarbons can be broken down by Pseudomonas sp and produced as biosurfactants (Muhammad Saleh Nasution, n.d.).

Finite element method (FEM)

The finite element method (FEM) can be used to resolve technical analytical problems using a numerical technique. The finite element approach uses different mathematical concepts to formulate equations for a linear or nonlinear system. It frequently generates over 20,000 equations, which is a very large quantity. Therefore, this strategy has little application unless a suitable computer is used (Chen et al., 2021; Efendi, 2022c; Elsanadedy et al., 2021; Gullett et al., 2020; Leslie et al., 2019; Singh & Harsha, 2018; Wang et al., 2022).

When a structure is exposed to forces like stress, pressure, temperature, flow rate, and heat, strain (deformation), stress, temperature, and flow rate are produced. How the resulting action (deformation) is distributed throughout the body is based on the properties of the force and stress system itself. The finite element method can be used to determine the distribution of this effect, which is expressed as displacement.

The finite element method uses an element discretization strategy to tackle the problem of determining the displacements of vertices, connections, lattices, and structural forces. The results of the matrix approach for structural analysis are identical to those of conventional structural analysis and are related to discrete element equations. There are approaches for discretizing one, two, or three dimensions (line elements, plane elements, and volume/continuum elements). (Gondhalekar & Panigrahi, 2021; Zhang et al., 2018)

LISA

LISA, a well-known finite element analysis tool, was used to estimate the temperature rise using three different models of heat exchangers. In decreasing order of complexity and simplicity of fabrication, the three different types of models are the line element model, the shell model, and the solid model.

Users only need to enter the element's dimensions in one dialog box and its thermal conductivity in another because LISA provides a variety of commonly used structural shapes for line elements.

The convection coefficient of the baseplate surface must be set at half the value used elsewhere for line element models only because convection cannot be totally ruled out when building the baseplate surface with the face selection tool. Actually, just apply common sense(Efendi, 2023).

For the other two models, it is easy to omit the mounting surface from convection; we just don't select that surface. In each case, an internal heat generator is used together with the assumption that the entire floor slab will serve as the heat source. Caution is required when applying boundary conditions to a line-el-ement model. When "Area" is chosen, LISA selects all of the line elements' surfaces. (Akcay et al., 2021; Efendi, 2022b, 2022d, 2022a; Efendi et al., 2022; Fumagalli et al., 2022; Milner et al., 2018; Qian, 2022).

Results and Discussion

Initial data for this study was derived from test findings in earlier work by Nasution, El (2017) The shear strength of the soil without bacteria, which served as a reference for the control value while measuring the shear strength of silt soil, was determined to be 163.49 kN/m^2, according to the results. In comparison to the findings of the silt soil test without bacteria, the shear strength of silt soil with a mixture of bacteria during a curing time of 15 days rose by 38.37% and 34.88%. Bacterial concentration in silt soil with a 30-day curing period can result in strength shear increases of 48.88% and 59.30%. The findings of earlier investigations and the link between the shear strength value and the soil's elastic modulus from the study are shown in table 1.

Table 1. Soil characteristic parameters

No.	Type Microbes Bacteria	Ripening Period (Day)	c=cu=k.N (kN/m^2)	Es = (500-1500) *Cu	Poison Rasio	Density (kN/m^3)
1	Existing soil samples	15	163.49	81,745.00	0.35	2.654
2	Bacilus Subtilis	15	226.22	113,110.00	0.35	2.654
3	Bacilus Subtilis	30	260.44	130,220.00	0.35	2.654
4	Pseudomonas sp	15	220.52	110,260.00	0.35	2.654
5	Pseudomonas sp	30	243.33	121,665.00	0.35	2.654

Source: Nasution (2017).

Modeling was done using 7 layers of different soil types and soil properties under the current conditions, with the first layer being 2 m thick and the soil parameters from earlier studies being adjusted in accordance with Table 1 before a load of 150 kN/m^2 was applied.

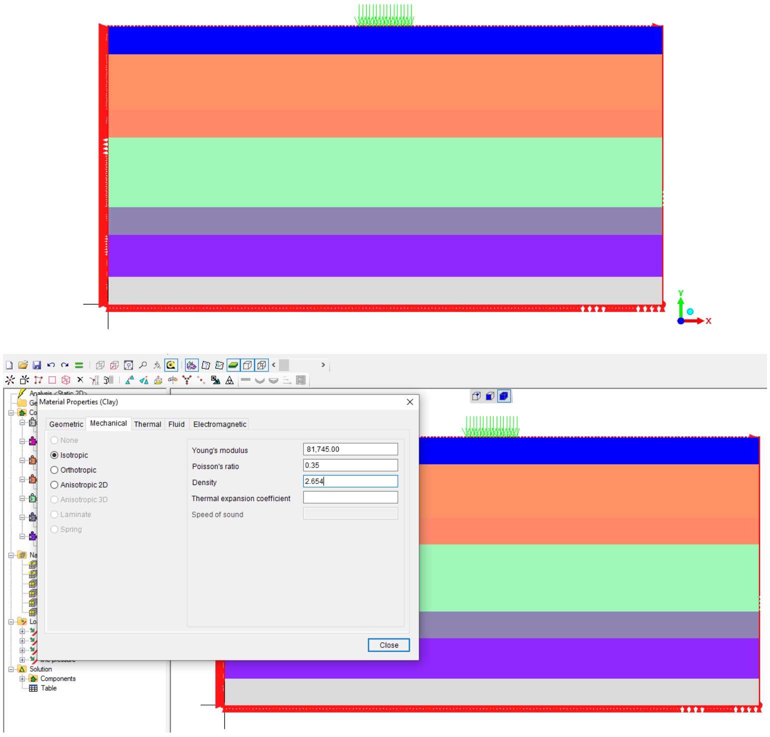

Figure 2. Initial soil modeling

The soil parameters used in the modeling in Figure 2 are the conditions of the existing soil or initial soil without being given a mixture of bacteria. Where changes only occur in the modulus of elasticity which comes from the test results to obtain the value of the shear strength of the soil material and is correlated to the soil elastic modulus.

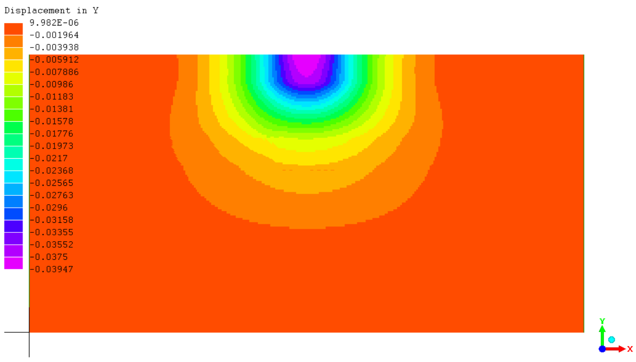

Figure 2. Settlement of existing soil that occurs due to load

In the initial soil material conditions when given a load of 150 kN/m^2 there was a decrease of 0.03947 m as shown in Figure 2, and the largest stress that occurred in the review area was 269.6 kN/m^2, shown in Figure 3.

Figure 3. Stresses in the existing soil that occur due to loads

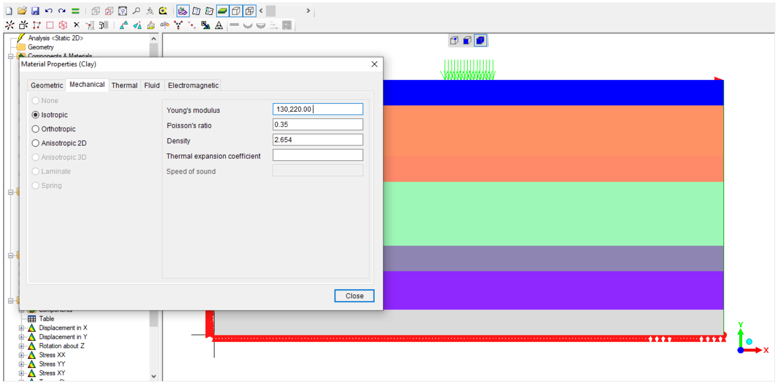

Figure 4. Soil modeling with the addition of Bacillus Subtilis bacteria that has been cured for 30 days.

The soil parameters used in the modeling in Figure 4 are the condition of the soil by adding Bacillus Subtilis bacteria which has been preserved for 30 days. Where changes only occur in the modulus of elasticity which comes from the test results to obtain the value of the shear strength of the soil material and is correlated with the modulus of elasticity of the soil.

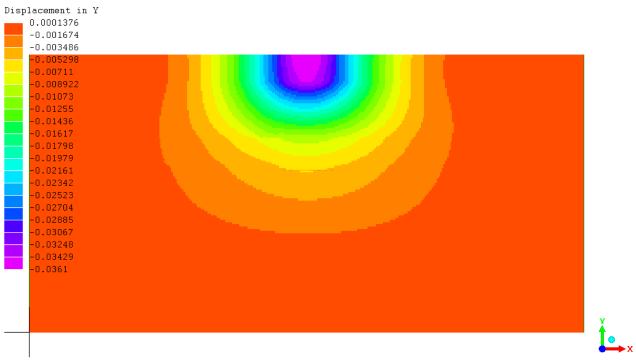

Figure 5. Soil subsidence that occurs by load with the addition of Bacillus Subtilis bacteria

In the condition of the soil material with the addition of Bacillus Subtilis bacteria which had been cured for 30 days and when given a load of 150 kN/m^2 there was a decrease of 0.0361 m as shown in Figure 5, this decreased decrease after being given Bacillus Subtilis bacteria which had been aged for 30 days by 0.00337 m or 3.37 mm, and the greatest stress that occurs in the viewing area is 339 kN/m^2 where it is up to 69.4 kN/m^2, shown in Figure 6.

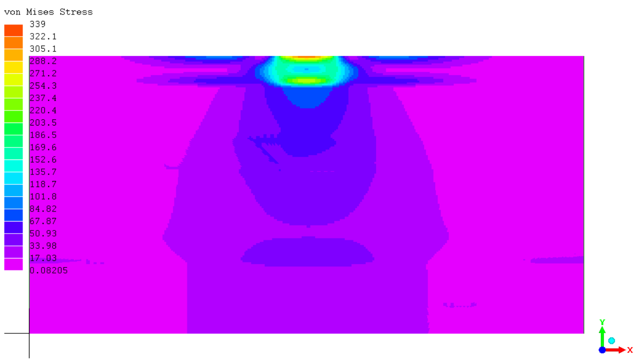

Figure 6. Soil stress that occurs by the load with the addition of Bacillus Subtilis bacteria

The soil parameters used in the modeling in Figure 7 are the condition of the soil by adding Pseudomonas sp bacteria which has been preserved for 30 days. Where changes only occur in the modulus of elasticity which comes from the test results to obtain the value of the shear strength of the soil material and is correlated with the modulus of elasticity of the soil.

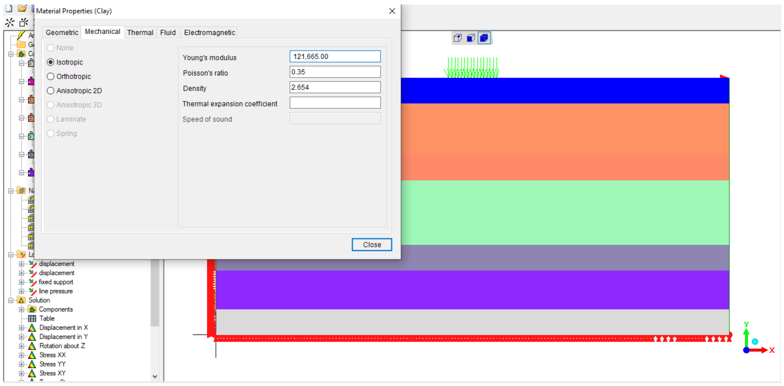

Figure 7. Soil modeling with the addition of Pseudomonas sp bacteria that has been cured for 30 days.

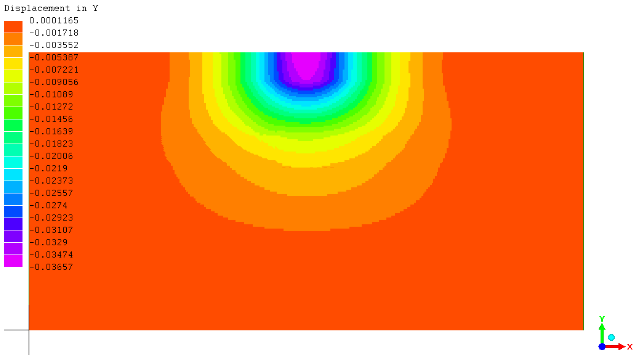

Figure 8. Soil subsidence that occurs by load with the addition of Pseudomonas sp bacteria

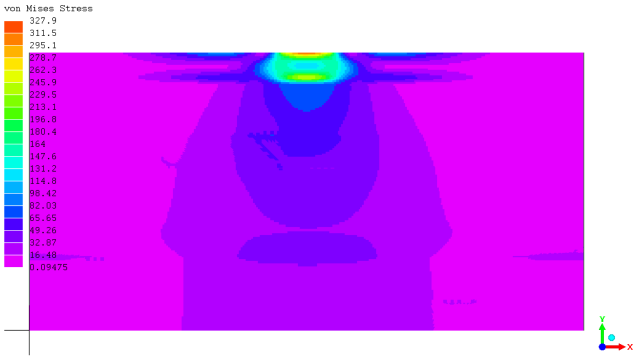

Figure 9. Soil stress that occurs by the load with the addition of Pseudomonas sp bacteria

In the condition of the soil material with the addition of Pseudomonas sp bacteria which had been cured for 30 days and when given a load of 150 kN/m^2 there was a decrease of 0.0365 m as shown in Figure 8, this decreased decrease after being given Pseudomonas sp bacteria which had been aged for 30 days by 0.0029 m or 2.9 mm, and the greatest stress that occurs in the viewing area is 327,9 kN/m^2 where it is up to 58,3 kN/m^2, shown in Figure 9.

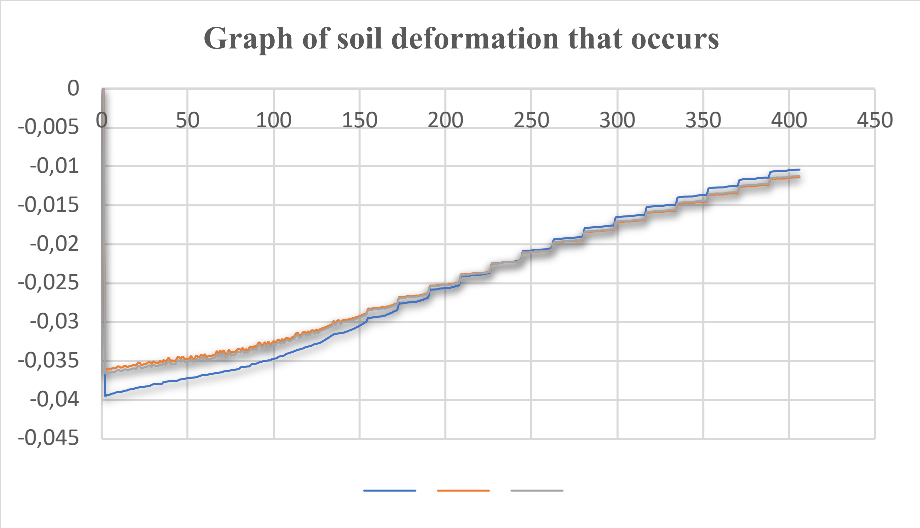

Figure 10. Graph of soil deformation that occurs

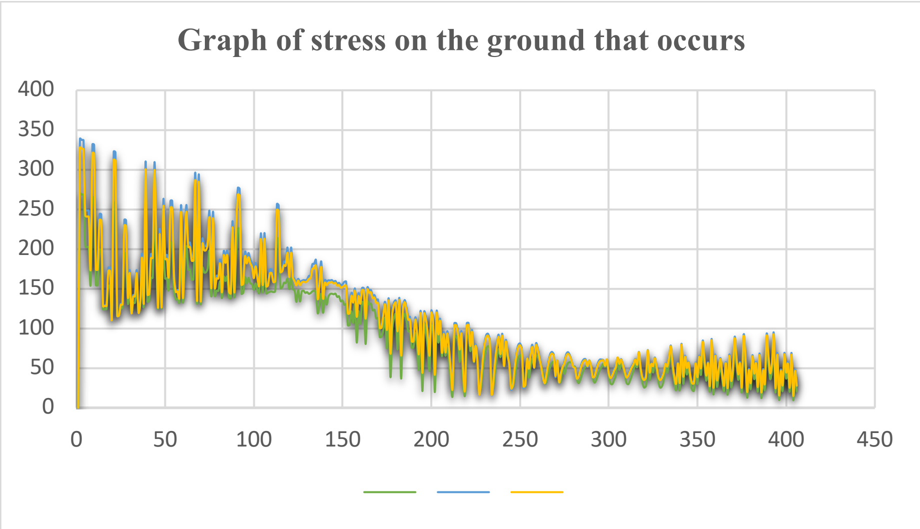

Figure 11. Graph of stress on the ground that occurs

From the graphs in Figures 10 and 11 it can be seen that there was a reduction in the occurrence of settlement after adding the two bacteria which had been aged for 30 days with a reduction in soil subsidence that occurred with the same pattern of behavior in the settlement area, but an increase in soil stress after the addition of the two bacteria this and the same voltage pattern as in figure 10-11.

CONCLUSION

From the results of the analysis using numerical analysis using the finite element method LISA V.8 FEA program, it can be seen that there is a reduc-tion in the occurrence of settlement after adding the two bacteria which have been aged for 30 days with a reduction in soil settlement of 2.9-2.27 mm de-spite an increase in stress. ranging from 58.3 to 69.4 kN/m^2.

References

Akcay, N., Gökalp, A. S., Günlemez, A., & ... (2021). Comparison of LISA vs INSURE Technique Using Nasal Intermittent Positive Pressure Ventilation (NIPPV) Support In Preterm Infants: A Randomized Controlled Trial. *Medical Journal of* .... https://search.ebscohost.com/login.aspx?direct=true\&profile=ehost\&scope=site\&authtype=crawler\&jrnl=13059319\&AN=150026811\&h=oa0JPzH%2F7kU0O6pXKM9bccbhmpQEDKIgq3iXNk0ZUZxlRjSTzIU5R%2BKnLbrndMQP950wl66%2B7Ip5scAz0%2BViPA%3D%3D\&crl=c

Burle, C. C. (2022). Effect of Semi Rigid Joints On Design of Steel Structure. *International Journal of Research in Engineering …*.

Chen, X., Pan, L., Xu, L., & Shi, C. (2021). Three-Dimensional Vehicle–Curved Track Dynamic Model Based on FEM and DEM. *… Journal of Structural Stability and …*. https://doi.org/10.1142/S0219455421501790

Costanzo, S., D'Aniello, M., Lorenzo, G. Di, & ... (2019). Seismic design of two-storey X-bracings. *… and Ductility of Steel …*.

Daudet, L. R., & Nguyen, H. (2018). Drift clip. *US Patent 10,087,617*.

Efendi, A. W. (2022a). Behavior Analysis of Building Structures After a Fire with FEA LISA V. 8. *Kurva S: Jurnal Keilmuan Dan Aplikasi Teknik …*. http://ejurnal.untag-smd.ac.id/index.php/TEKNIKD/article/view/6413

Efendi, A. W. (2022b). Behavior of railroad bearing due to temperature and load using LISA FEA. *Journal of Railway Transportation and Technology*. https://jrtt.org/index.php/jrtt/article/view/1

Efendi, A. W. (2022c). Computing steel frame analysis of behavior semi-rigid connection. *International Journal of Advanced Science and …*. http://www.ijasca.org/index.php/ijasca/article/view/17

Efendi, A. W. (2022d). Structural Design Tuak River Pedestrian Suspension Bridge Anchor Block Type Rigid Symmetric with LISA. *Elektriese: Jurnal Sains Dan Teknologi Elektro*. https://jurnal.itscience.org/index.php/elektriese/article/view/1572

Efendi, A. W. (2023). Simulation of fire exposure behavior to building structural elements using LISA FEA V. 8. *International Journal of Advanced Science and …*. http://www.ijasca.org/index.php/ijasca/article/view/31

Efendi, A. W., Do, Y., & Rachman, N. F. (2022). Behavior of Rail Ballast Layer Using Mortar Foam with LISA-FEA. *Journal of Railway Transportation and …*. https://www.jrtt.org/index.php/jrtt/article/view/8

Elsanadedy, H. M., Al-Salloum, Y. A., Alrubaidi, M. A., & ... (2021). Finite element analysis for progressive collapse potential of precast concrete beam-to-column connections strengthened with steel plates. *Journal of Building …*. https://www.sciencedirect.com/science/article/pii/S2352710220335087

Faridmehr, I., Tahir, M. M., Lahmer, T., & Osman, M. H. (2017). Seismic performance of steel frames with semirigid connections. *Journal of Engineering*.

FRAME, L. (n.d.). ДГКМ MASE. *Academia.Edu*.

Fumagalli, J., Pieroni, M., Renaux-Petel, S., & ... (2022). Detecting primordial features with LISA. *Journal of Cosmology …*. https://doi.org/10.1088/1475-7516/2022/07/020

Gondhalekar, T. M., & Panigrahi, S. K. (2021). Transient Analysis of Railway Sleeper using Three-Dimensional Finite Element Method. *Journal of The Institution of Engineers …*. https://doi.org/10.1007/s40030-021-00582-5

Gullett, P. M., Dickey, M. M., & Howard, I. L. (2020). Finite Element Analysis of Highway Bridges Subjected to Hurricane Storm Surge via the AMBUSH Framework. *Journal of Bridge Engineering*. https://doi.org/10.1061/%28ASCE%29BE.1943-5592.0001602

Hoehler, M. S., Smith, C. M., Hutchinson, T. C., Wang, X., & ... (2017). Behavior of steel-sheathed shear walls subjected to seismic and fire loads. *Fire Safety Journal*.

IFFAH FADLIAH. (2013). *EKSPERIMENTAL ON SANDY CLAY SOIL STABILIZATION BY BIOGROUTING BACILLUS SUBTILIS*. PROGRAM PASCASARJANA PROGRAM STUDI MAGISTER TEKNIK SIPIL FAKULTAS TEKNIK UNIVERSITAS HASANUDDIN MAKASSAR.

Jack W, Lucy Jap, Marcelia Sugata, Anastasia Zakaria, Felix Lie, & Tan Tjie Yan. (2022). Stabilisasi Tanah dengan Metode Biogrouting. *Universitas Pelita Harapan*.

Jeyarajan, S., Liew, J. Y. R., & Koh, C. G. (2015). Analysis of steel-concrete composite buildings for blast induced progressive collapse. *International Journal of …*. https://doi.org/10.1260/2041-4196.6.3.457

Leslie, W. D., Luo, Y., Yang, S., Goertzen, A. L., & ... (2019). Fracture risk indices from DXA-based finite element analysis predict incident fractures independently from FRAX: The Manitoba BMD Registry. *Journal of Clinical …*. https://www.sciencedirect.com/science/article/pii/S1094695018302816

Mahawish, A., Bouazza, A., & ... (2016). Biogrouting coarse materials using soil-lift treatment strategy. *… Geotechnical Journal*. https://doi.org/10.1139/cgj-2016-0167

Mashalkar, M. R. V, & Narkhede, M. T. (n.d.). Review on Dynamic Evaluation of Wind & Earthquake Forces Resisting Systems for Tall Building. In *Academia.edu*.

Mazzolani, F., Ricles, J. M., & Sause, R. (2009). *Behaviour of Steel Structures in Seismic Areas: STESSA 2009*. books.google.com.

McCormick, J., Fadden, M., & Buison, J. (2010). Cyclic testing of hollow structural sections for seismic applications in low to mid-rise moment frames. *Tubular Structures XIII*.

Milner, D., Wesevich, J., Nikodym, L., Nasri, V., & ... (2018). Improved blast capacity of pre-engineered metal buildings using coupled CFD and FEA modeling. *Journal of Loss* …. https://www.sciencedirect.com/science/article/pii/S0950423018300949

Muhammad Saleh Nasution. (n.d.). *PENURUNAN PERMEABILITAS DAN PENINGKATAN KUAT GESER TANAH LANAU MENGGUNAKAN PENGARUH MIKROBAKTERI BACILLUS SUBTILIS DAN PSEUDOMONAS SP*.

Muhammad Saleh Nasution, Yusep Muslih Purwana, & Bambang Setiawan. (2017). PENURUNAN PERMEABILITAS DAN PENINGKATAN KUAT GESER TANAH LANAU MENGGUNAKAN PENGARUH MIKROBAKTERI BACILLUS SUBTILIS DAN PSEUDOMONAS SP. *E-Jurnal MATRIKS TEKNIK SIPIL*, 1391.

NANDA AFIANDA. (2022). *STABILISASI TANAH GAMBUT DENGAN TEKNIK BIOGROUTING MELALUI BANTUAN BAKTERI*. PROGRAM STUDI TEKNIK SIPIL FAKULTAS TEKNIK UNIVERSITAS ISLAM RIAU PEKANBARU.

Nikoukalam, M. T., Mirghaderi, S. R., & ... (2015). Analytical study of moment-resisting frames retrofitted with shear slotted bolted connection. *Journal of Structural* ….

Qian, C. (2022). Mechanism of bacterial control of mineralisation gradient at the surface layer of cement-based materials. In *Advances in Cement Research* (Vol. 34, Issue 3, pp. 93–108). https://doi.org/10.1680/jadcr.21.00106

Shakeel, S., Fiorino, L., & Landolfo, R. (2020). Behavior factor evaluation of CFS wood sheathed shear walls according to FEMA P695 for Eurocodes. *Engineering Structures*.

Singh, P., & Harsha, S. P. (2018). Finite Element Analysis of Cartridge Tapered Roller Bearing of Freight Wagon. *International Journal of Vehicle Structures and* …. http://ischolar.info/index.php/IJVSS/article/view/185330

Tapes, C. (2020). *Cold-Formed Sigma Beams Retrofitted by Bonded*.

Taufik, S. (2008). *Behaviour of bolted connections with high strength and stainless steel*. search.proquest.com.

Wang, Z. Y., Jin, Y. F., Yin, Z. Y., & ... (2022). A novel coupled NS-PFEM with stable nodal integration and polynomial pressure projection for geotechnical problems. … *Journal for Numerical and* …. https://doi.org/10.1002/nag.3417

Wu, C., & Chu, J. (2020). Biogrouting method for stronger bond strength for aggregates. *Journal of Geotechnical and Geoenvironmental* …. https://doi.org/10.1061/%28ASCE%29GT.1943-5606.0002386

Wu, C., Chu, J., Cheng, L., & Wu, S. (2019). Biogrouting of aggregates using premixed injection method with or without pH adjustment. *Journal of Materials in Civil* …. https://doi.org/10.1061/(ASCE)MT.1943-5533.0002874

Yang, R., & Zhou, X. (2019). Experimental Research and Theoretical Analysis of the Seismic Behavior of Prefabricated Semirigid Steel Frame with X-Shaped Braces. *Advances in Civil Engineering*.

Yuan, H., Hong, H. P., Deng, H., & Bai, Y. (2018). Displacement ductility of staged construction-steel tube-reinforced concrete columns. *Construction and Building Materials*.

Zhang, W., Yuan, W., & Dai, B. (2018). Smoothed particle finite-element method for large-deformation problems in geomechanics. In *International Journal of Geomechanics*. researchgate.net. https://www.researchgate.net/profile/Wei-Zhang-276/publication/322624095_Smoothed_Particle_Finite-Element_Method_for_Large-Deformation_Problems_in_Geomechanics/links/5b357f69a6fdcc8506db60ef/Smoothed-Particle-Finite-Element-Method-for-Large-Deformation-Problems-in-Geomechanics.pdf