Modeling of soil subsidence in IKN using numerical analysis of the finite element method LISA V.8

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ABSTRACT: The Ibu Kota Negara area in Indonesia (hereafter referred to as IKN) is dominated by hilly areas and broad plains, Due to the soil characteristics and land elevations, disasters such as landslides and land subsidence often occur. This study compares the results of LISA with that of a geotechnical analysis software. It is hoped that the results of this study will show the usefulness of LISA for geotechnical analysis. For example the results of the geotechnical software shows a settlement depth of 0.0623 meters as shown in Figure 8(d), and with LISA the settlement occurs at the same depth of 0.0633 meters.

Keywords: *Geotechnical, FEA, LISA, Subsidence, Soil*

ABSTRAK: Wilayah IKN didominasi oleh daerah perbukitan dan dataran yang luas, Melihat karakteristik tanah yang beragam dan elevasi tanah yang bervariasi, sering terjadi bencana seperti tanah longsor dan penurunan muka tanah. Penelitian ini memvalidasi hasil LISA terhadap program analisis geoteknik yang sangat sering digunakan dan khusus untuk perangkat lunak geoteknik. Diharapkan hasil penelitian ini dapat memberikan sumbangsih bagi dunia geoteknik khususnya menjadi khazanah baru dengan menggunakan metode elemen hingga LISA V.8 FEA. Untuk sudut penurunan yang terjadi adalah 0,0623 meter seperti terlihat pada Gambar 8(d), dimana pada analisis menggunakan software geoteknik, penurunan yang terjadi pada titik yang sama pada tinjauan adalah 0,0633 meter, terdapat perbedaan yang tidak signifikan dengan rasio 1,016 dari hasil software geoteknik dengan hasil LISA V.8 FEA.

Kata Kunci: Geoteknik, FEA, LISA, Penurunan, Tanah

1. Introduction

The IKN area is dominated by hilly areas and broad plains. The Balang Island rock formation site (Tmbp) sits above the Bebulu Formation. This formation is composed of interspersed granite and quartz sandstones with irregular interjections of limestone, claystone, coal, and dacite tuff. The age of the Pulau Balang Formation is Middle Miocene with a land of shallow sea deposits. This area also intersects with the Balikpapan Formation (Tmpb) formed in a deltaic or littoral depositional environment to open shallow sea, with an age range of Middle Miocene to Late Miocene. Seeing the various soil characteristics and varying land elevations, disasters such as landslides and land subsidence often occur as seen in figure 1.

This study of the behavior of land subsidence uses the finite element method and the LISA software in particular. LISA is used widely in the analysis of structural materials behavior for construction and industrial products.

The simulation is first done with a node-based smoothed particle finite element method and then compared with analytical solutions or results from other numerical methods to validate the correctness and efficiency of the approach (Wang et al., 2022). PFEM is a numerical approach to solve large displacement and large strain continuum problems that are beyond the capabilities of classical finite element method(Carbonell et al., 2022). This study compares the results of LISA against a geotechnical analysis software that is very often used. It is hoped that the results of this study will demonstrate the usefulness of LISA geotechnical analysis.

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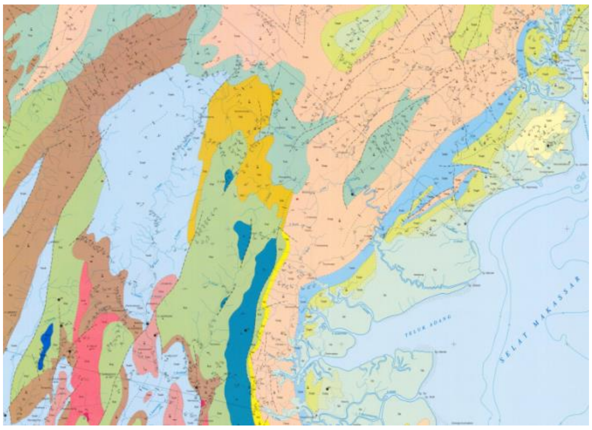


Figure 1. Map of geological formations in the IKN area
(East Kalimantan geotechnical map, 2022)

2. Methods

2.1 Soil data from field investigation

This research was conducted by collecting soil samples by boring a region of the IKN area. The sample labeled BH 03 is the mini pier area owned by local residents, the laboratory results of which are listed in the adjacent table. Multiscale models are used to examine the influence of consolidants on the mechanical properties of the samples. Comparison between the modeling and experimental results shows a satisfactory agreement(Zhang et al., 2022). In the finite element method (FEM), in order for the physical behaviour of the soils correctly captures it's material properties must be correctly calibrated (León et al., 2022). The material properties of each soil layer is modeled using geotechnical software to obtain soil subsidence behavior, these same properties will be in the model built with the LISA software.

The following table lists the soil properties from the bored samples:

Table 1. Summary of the results from the bored soil

Boring No.	Soil Unit Number (m)		Soil Type	Sub Soil Unit Number (m)		Consistency/ Density	NSPT (Blows /30 cm)
				1	0-1	-	-
				2	1-5	Soft	4/30
	1	0-15	Clay	3	5-7	Medium	8/30
BH.03				4	7-13	Very Stiff	22-29/30
				5	13-15	Hard	41/30
	2	15-18	Sandy Clay	6	15-18	Hard	50-60/30
	3	18-20	Clay	7	18-20	Hard	2>60

This is the soil layer profile from the residential & dock construction project at North Penajam Paser. The layer profile can be generally described as follows:

Depth : 0.00-20.00 m
Soil type : clay containing sand at a depth of 15.00 - 18.00 meters, with an N SPT value of 4 - 60; at that point there is a water content (w) of 17.46% - 68.41%,
Bulk weight (γ) : 1.62 (gram/cm^3) - 1.70 (gram/cm^3),
Specific gravity (Gs) : 2.58 - 2.62
LL : 40.68% - 55.20%
PL : 17.42% - 25.58%
PI : 23.26% - 30.89%
Clay : 42.29% - 76.65%
Silt : 14.43% - 41.63%
Sand : 6.46% - 14.50%
Gravel : 0.52% - 5.36%
Unconfined (qu) : 0.225 (kg/cm^2) - 2.097 (kg/cm^2)
Shear angle (ø) : 18.172˚ - 18.723˚
Cohesion (c) : 0.225 (kg/cm^2) - 0.357 (kg/cm^2)
Consolidation Cv : 0.145 x 10^{-3} (cm^2/sec) - 0.234 x 10^{-3} (cm^2/sec)
Cc : 0.100 - 0.562.

The data from this soil investigation is illustrated in the form of a graph of the N SPT value in each soil layer(Ganiyu et al., 2021; Recep & Sedat, 2021; U & Horsfall, 2020) as shown in Figure 2 below:

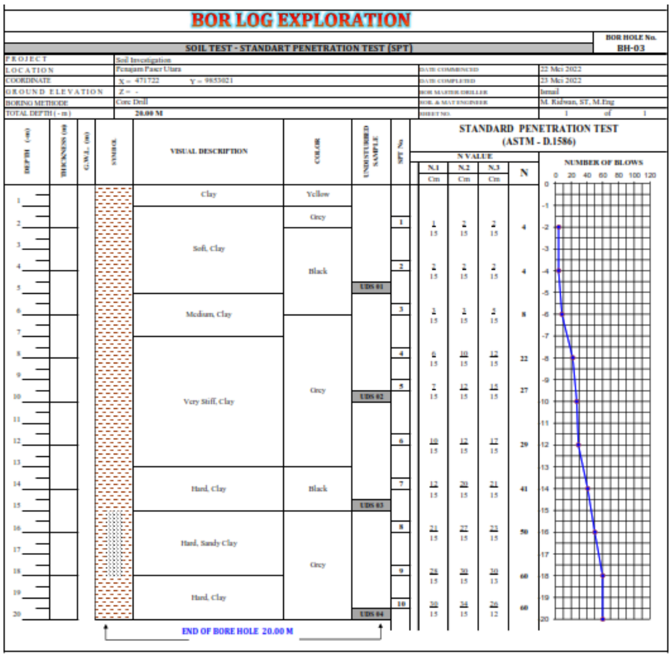


Figure 2. Graph of soil investigation result
(Results of soil investigation report, 2022)

2.2 Finite element analysis

The finite element method (FEM) is a numerical method for solving physics problems using numerical methods which otherwise cannot be solved by analytical methods. As a result of the finite element method, equations of a linear or nonlinear system need to be solved. The number of equations generated is in proportion to the number of elements and element types being used, which results in a very high number of equations, necessitating the use of a computer (Song et al., 2017).

When a structure is subjected to forces, pressure, temperature differentials or flow, structures will deform (strain) and become stressed (Efendi, 2022a).

LISA, a popular finite element analysis application, and was used to estimate the temperature rise for three different models of heat exchangers. The three types of models, in order of their simplicity and ease of construction are a line element model, a shell model, and a solid model(Efendi, 2022b).

LISA provides a menu of commonly used structural shapes, users need only specify relevant dimensions to generate the mesh. The thermal conductivity associated with the elements must be specified in the material properties for those elements.

3. Results and Discussion

Using the soil investigation data, researchers used geotechnical software to get the results of the soil subsidence behavior. These results were used for comparison with the results of the model made with LISA fea software.

The geotechnical software modeling as shown in Figure 3, is modeled in the form of open land in accordance with existing conditions at the location, by reviewing a width of 40 meters and a depth according to the results of soil investigations, where the value of N SPT > 30 occurs up to a depth of 20 meters.

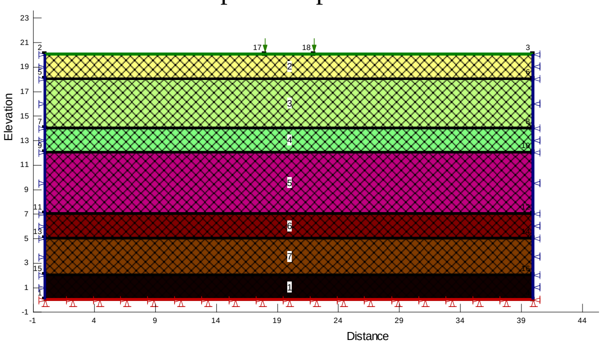


Figure 3. Soil modeling in geotechnical software

(Results of geotechnical analysis software, 2022)

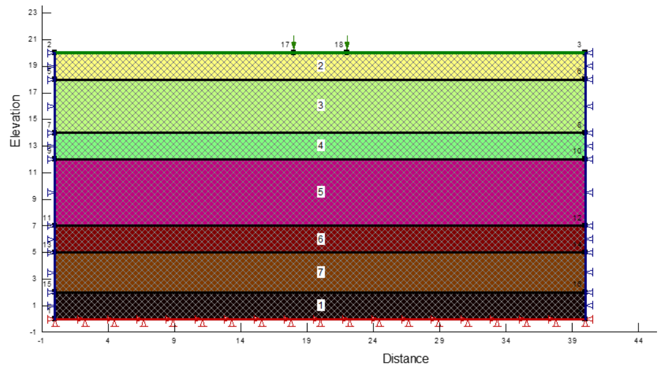
Table 2 lists the material properties from the laboratory tests and were used in both the geotechnical software and LISA (Atibrata & Listyawan, 2020).

Tabel 2. Soil properties data

Depth (m)	Soil Type	Density (kN/m3)	N SPT Average	EFEKTIF STRESS	Es (kN/m^2)	v
				c=cu=k.N (kN/m^2)	Es =(500 s/d 1500)* Cu	
0						
	Clay	16.30	4	20.00	10000	0.4
2						
	Soft clay	16.30	4.3	21.67	10833.3	0.4
6						
	Medium Clay	16.20	10.3	51.67	25833.3	0.3
8						
	Very Stiff, Clay	16.20	19.8	98.75	49375	0.3
13						
	Hard Clay	16.90	30.7	153.33	76666.7	0.2
15						
	Hard Sandy Clay	16.90	37.0	185.00	92500	0.2
18						
	Hard Clay 2	17.00	40.3	201.67	100833	0.2
20						

Results of soil investigation report, 2022

These material properties were applied to each layer of soil type. The model is bears a center load of 152 kN, 18-22 meters (node 17,18) from the origin, as shown in Figure 4.



(a)

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Color	Name	Model	Young's Modulus (E) (kPa)	Unit Weight (kN/m³)	Poisson's Ratio
	Clay	Linear Elastic (Total)	10,000	16.3	0.42
	Hard Clay	Linear Elastic (Total)	76,666.667	16.9	0.2
	Hard Clay (2)	Linear Elastic (Total)	100,833.33	17	0.15
	Hard Sandy Clay	Linear Elastic (Total)	92,500	16.9	0.15
	Medium Clay	Linear Elastic (Total)	25,833	16.2	0.3
	Soft Clay	Linear Elastic (Total)	10,833	16.3	0.4
	Very Stiff, Clay	Linear Elastic (Total)	49,375	16.3	0.25

(b)

Figure 4. (a) Soil modeling using load (b) soil material parameters
(Results of geotechnical analysis software, 2022)

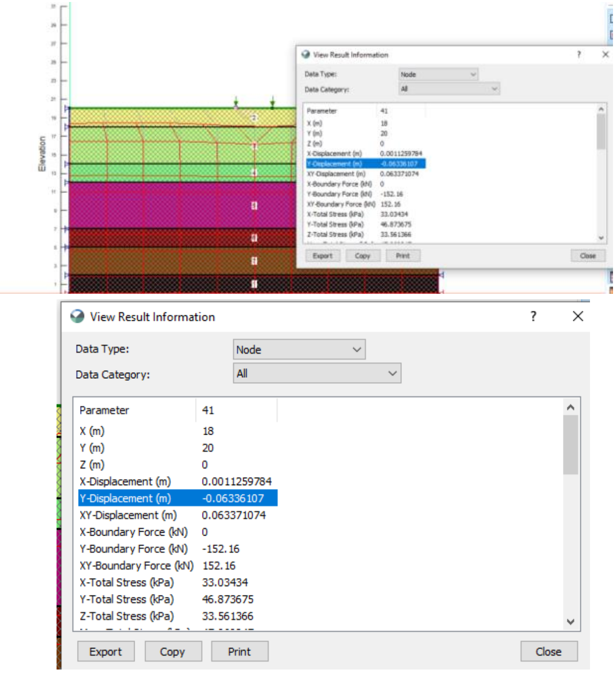


Figure 5. Land subsidence analysis results

(Results of geotechnical analysis software, 2022)

From the results of the geotechnical software, it was found that the occurrence of a settlement on the Y axis due to the load of 152.16 kN was -0.063 m, as shown in Figure 5.

The model made with LISA same depth and constraints on the right and left sides of the soil layer so that they can displace vertically but not horizontally. The lowest edge is fully constrained to eliminate all motion.

Figure 6 shows that the soil has been modeled in LISA using 4 node shell elements quadrilateral elements.

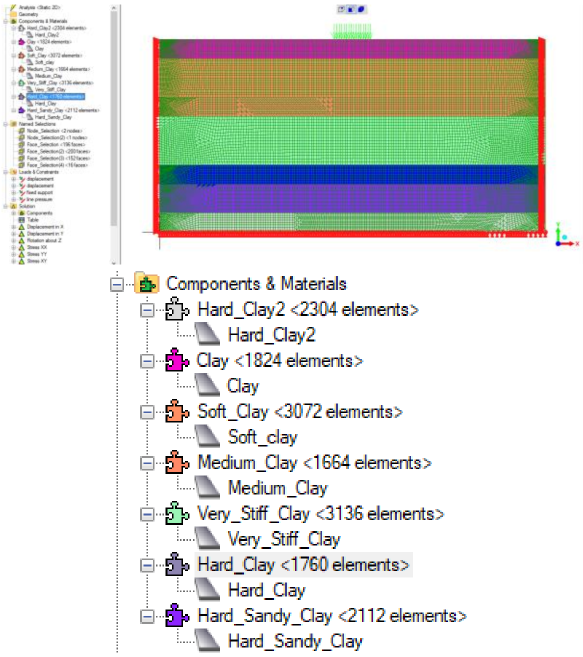
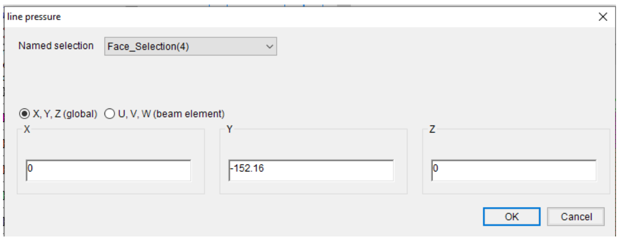


Figure 6. Soil layer and material using LISA FEA (2022)

While all the modeling parameters between the model made in the geotechnical software are the same as the model made in LISA, there are differences in the meshing patterns. But this does not have any significant effect upon the results.



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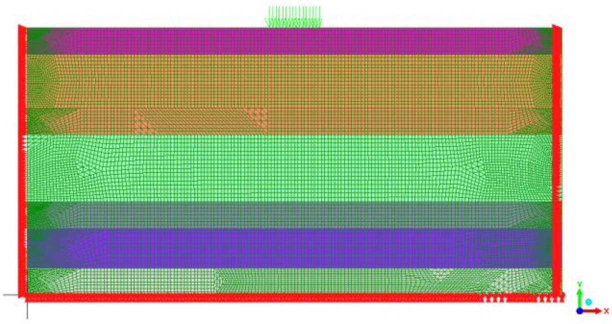
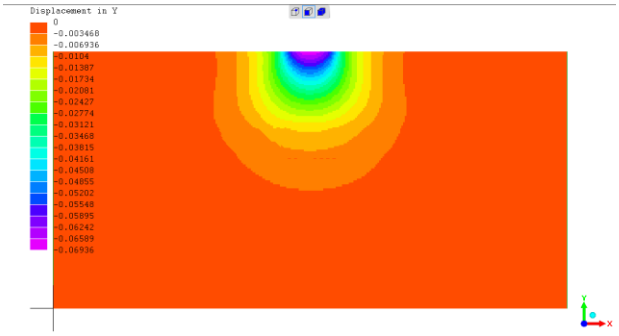


(b)

Figure 7. (a) load parameter (b) meshing area (LISA, 2022)



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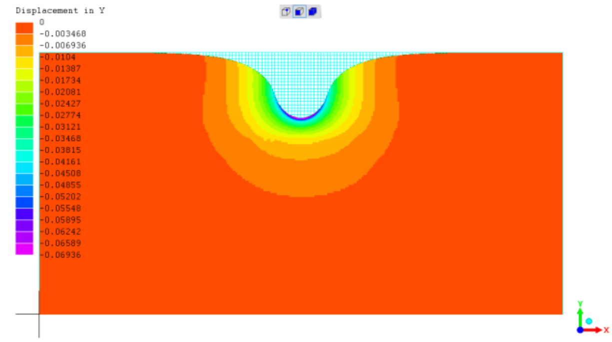

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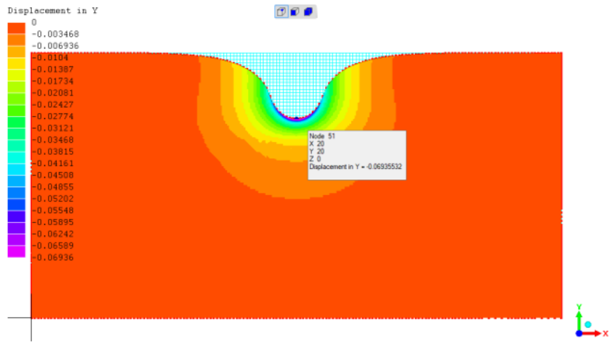

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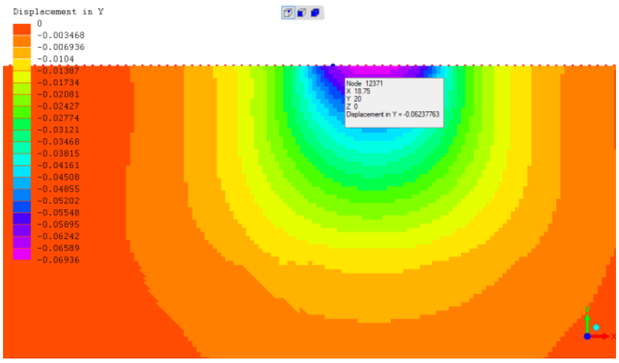

(d)

Figure 8.
(LISA, 2022)

The above images are the results from LISA. It can be seen that the land subsidence that occurs after loading is 152.16 kN in agreement the geotechnical software results shown in Figure 5. The maximum settlement value is 0. 06936 meters as seen in Figure 8(a)(b). In Figure 8(d) the point for comparison with the geotechnical software shwos a settlement of 0.0623m in LISA and at the same point in the geotechnical software it is 0.0633 meters which is an insignificant difference.

4. Conclusion

While LISA is used for structural analysis, this study demonstrates that LISA can also be used in soil subsidence analysis as it gives almost the same results as specialized geotechnical analysis software.

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