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Analysis of concrete slab and ground settlement due to reach stacker and container load at Labuan Bajo Port Terminal

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Abstract

The container yard is one part of the dock terminal that stores containers. The busier a dock is linear the higher the need for a container yard. So good planning is needed with a long service life. Stackers and containers reach the influential loads in container yard concrete slab planning. The weight of the reach stalker which reaches 71.8 tons and the weight of the container reaches 6 tons /m2 is an important reason to analyze how thick the safe pavement is for these loads which continue to increase along with the increase in the busyness of a pier. This study analyzed the thickness of the concrete slab and the subsidence that occurred in a container yard of 1.36 Ha with a container area of 20 feet. The analysis was carried out with a concrete quality of 30Mpa and the calculation of soil subsidence was analyzed using a geogrid that helped maintain soil stability. The results of this study obtained a safe pavement thickness of 35cm with a safe decline following SNI 8460: 2017 standards regarding soil settlement.

Keywords

Concrete slab settlement, reach stacker, container load, Labuan Bajo Port Terminal

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Introduction

Containers are a means of shipping cargo that is currently often used in world trade. Statistical data shows that more than 90% of international cargo is transported via sea mode with ports as its transfer interface [4]. In addition, cargo and shipping from all over the world also experienced a trend of increasing exponentially [2][3]. In this order, container terminals try to overcome various obstacles so that operational productivity increases and eventually terminal capacity becomes higher.

The rapid development of export and import volumes has led to the need for safer and more efficient delivery of goods and various demands from service users to continue to improve services so that companies engaged in containers become more competitive. Handling container systems (containers) requires a container stacking place, namely landfilling [1].

The pavement used is pavement pavement, with the request for acceleration in project implementation time, from the project team proposing to review the pavement design of paving blocks into rigid pavement, because rigid pavement is considered more effective and efficient on implementation time. Therefore, it is necessary to analyze the calculation of rigid pavement [1] [6].

The purpose of this study is to analyze the thickness of concrete slabs to withstand reach stacker and container loads with AASHTO method calculations and analyze land subsidence in the container yard area due to reach stacker and container loads using the help of the 3D PLAXIS application.

Method

Standard Analysis

Rigid pavement analysis in the container yard area in the Wae Kelambu terminal project of Labuan Bajo Port uses standard:

a. AASHTO 1993, Guide for Design of Pavement Structure

b. SE DIRJEN Pavement Design Manual 2017

c. Pd-T-14-2003 Cement concrete road pavement planning

The software used to help analyze the data in this paper is PLAXIS 3 Dimensions for material specifications can be seen in Table 1.

Table 1. Material specification

Material	
Concrete	f'c = 28,53 Mpa
Portland cement	Type 1
Subgrade	CBR 6%
Foundation layer type and thickness	thicknesses 20cm, Aggregate CBR 35%
Plan life of the concrete pavement	40 year
Traffic growth factor	4,75%
Directional Distribution Coefficient and Load Safety Factor	0,45
Load Safety Factor	1,1 (freeways and arterial roads with medium commercial (4 roadways lines)

Research Location

The location was analyzed at the liquid bulk dock of the Labuan Bajo Port Multipurpose Terminal - NTT (Figure 1).

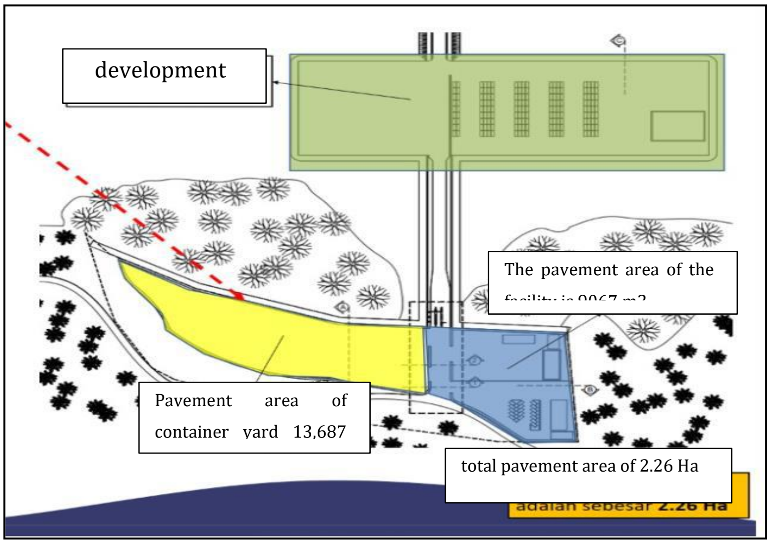

Figure 1. Location

During the 40-year service life (JSKN), there will be 33000875 axes with three stacked containers, whereas the JSKN plan is 1485394. The reach stacker's axe count yields a JSKN of 1650438, whereas the 40-year plan JSKN is 742396.9.

Analysis of Occurring Axis Repetitions

Figuring out the Axis The following formula is used to calculate the axis percentage spectrum to account for repetition:

$$\text{Axis proportions: } \frac{\text{total number of axes (STRT?STRG?STdRTG/STdRG)}}{\textit{total number of axes}} \quad (1)$$

Traffic reps based on PD-T-14-2003 can be calculated as follows:

$$\text{Load Proportion: } \frac{\text{total of number axes } \left(\text{STRT?STRG?}\frac{\text{STdRTG}}{\text{STdRG}}\right)}{\text{total jutotal of number axes}} \quad (2)$$

With the calculation of the formula above, the traffic load repetition for 3 containers is 1.49E+06 and for the reach stacker axis is 7.43E+05.

Thickness of Pavement Analysis

In determining the pavement thickness, Guideline No. Pd-T-14-2003 Cement Concrete Pavement Planning is used, which is more specific than MPJ 2017. First, to obtain the effective subgrade CBR value, the foundation layer with a 100 mm thick binder is determined, and the minimum subgrade CBR is 10%. Then with the graph in Figure 4.2. below, an effective CBR of 25% was obtained.

Next, erosion and fatigue control calculations are carried out, with the value of the plan load per wheel using the following formula:

$$\text{load safety per rod=} \frac{\text{Axis load (kN)x loadsafety factor}}{\textit{number of wheelbases}} \quad (3)$$

Calculation of Equivalent Stress and Erosion Factor due to 6 ton/m2 container load. Because the pavement at Labuan Bajo Port is planned without concrete shoulders, and the thickness of the plane taken is 280 mm (28 cm), the Erosion Factor and Equivalent Stress are obtained from the following Table 2.

With K-350 Concrete Quality, Fcf = 4.14 Mpa is obtained. For basic ground, CBR plans are obtained at 10% and effective CBR at 25%. So that the thick pavement design to be tested against permit reps has the following coefficients. Pavement Thickness plan = 28 cm so from Table 2 it is obtained.

Table 2. Standard of pavement analysis

Standard		
TE STRT	:	0.55
TE STRG	:	0.9
TE STdRG	:	0.78
TE STrRG	:	0.59
FE STRT	:	1.75
FE STRG	:	2.35
FE STdRG	:	2.48
FE STrRG	:	2.56
FRT STRT	:	0.133
FRT STRG	:	0.217
FRT STdRG	:	0.188
FRT STrRG	:	0.142

The coefficients already obtained are used to determine the repetition of permission with the help of a nomogram. Analysis of fatigue and erosion obtained from the nomogram is then calculated on the percent damaged. The percentage of damage to fatigue analysis and erosion analysis should be less than 100%. If it is more than 100%, then the thickness of the concrete plate or concrete quality must be enlarged by doing *trial* and *error calculations.* From the results of fatigue and erosion analysis, a concrete slab with a thickness of 280 mm can withstand *containers* of 6 tons / m2.

Analysis of Equivalent Stress and Erosion Factor Due to Reach Stacker Load

Based on Pd-T-14-2003 Calculation of the *load of the reach stacker* is used with a thickness of 350 mm. The value of FRT (Voltage Ratio Factor) is obtained by calculation using the following formula:

$$FRT = \frac{FE}{Fcf} \quad (4)$$

With the quality of fc' concrete 28.53 MPa, Fcf = 4.14 Mpa is obtained. So that the thick pavement design is to be tested against rep permits then CBR basic ground plan 10%, CBR effective 25%, Pavement thickness plan 35 cm (Table 3).

Table 3. Standard of pavement analysis due stacker load

Standard		
TE STRT	:	0.43
TE STRG	:	0.75
TE STdRG	:	0.74
TE STrRG	:	0.56
FE STRT	:	1.5
FE STRG	:	2.1

Standard		
FE STdRG	:	2.33
FE STrRG	:	2.52
FRT STRT	:	0.104
FRT STRG	:	0.181
FRT STdRG	:	0.179

The coefficient obtained is used to determine permit reps with the help of a nomogram in Cement Concrete Road Pavement Planning, Pd-T-14-200.

Fatigue control and erosion analysis are simply not possible for the calculation of wheel load on the reach stacker because the vehicle axis load is greater than the maximum load per wheel on the fatigue and erosion analysis chart of 65 kN or 6.5 tons. Therefore, to find out whether the concrete pavement can withstand the plant load per wheel on the reach stacker

Analysis of Concrete Shear and Compressive Forces against Reach Stacker Loads

After analyzing the shear force and compressive force of concrete against the reach stacker *load, the selection of concrete slab thickness was carried out with fc'* 29.7 Mpa, fy (deform) 400 MPa, plain fy 240 MPa, with slab width (b) 1000mm and slab thickness (h) 350 mm where for load shear force control plan per wheel (STRT), show in Table 4.

Table 4. Standard of load analysis of concrete shear

Standard		
Load per wheel (STRT)	P STRT	172 kN/m²
Plan load per wheel (STRG)	PSTRG	94 kN/m²
Load factor (Pd-T-14-2003)	Fb	1.1
Front-wheel plan shear force (STRT)	Vu STRT	190 kN/m²
Rear wheel plan shear force (STRG)	Vu STRG	104 kN/m²

Front Wheel Plan Load

In front-wheel plan load planning, the effective height (d) is 350 mm, the Plan shear force due to dynamic load Vu = 190 kN/m2, the shear strength reduction factor (f) is 0.6, the melting stress of the shear reinforcement (fy) is present; ah 240 Mpa, while the shear strength of concrete (Vn) is 317.903 kN/m2, the shear resistance of concrete obtained is 190.742 kN/m2. To withstand the shear force, it is necessary whether or not the sliding reinforcement is determined by: ØVn > Vu. From the calculation results obtained:190,742> 190. It is known that concrete slabs can withstand the shear forces that occur.

Rear Wheel Plan Load (STRG)

Planning rear wheel plan load (STRG) with an effective height of 350 mm and plan shear force that occurs due to dynamic load (Vu) is 104 kN/m2. The shear strength reduction factor (f) is 0.6. The melting stress of the shear reinforcement (fy) is 240 Mpa with a concrete shear strength of 317.93 kN/m2. Concrete shear resistance of 190,742 kN/m2. The value of the concrete slab resists the shear forces that occur where the compressive stress control with the compressive strength of fc' concrete is 29.7 Mpa and the melting stress of steel is 400 Mpa. The shear reinforcement of the planned slab width is 1000 mm and thickness (h) 350 mm then the resulting concrete compressive force (Vu) is 190 kN/m2.

Based on SNI 2847-2019 Subject 18.4: Serviceability requirements - components of stress bending structures in concrete under compressive conditions due to prestress should not exceed 0.45 fc'. Thus, the concrete slab is still able to withstand compressive forces of 190 kN/m2

Analysis of Dowel and Tie Bar Reinforcement

1. Transverse Connection (Dowel)

Based on PD-14-2003, the horizontal connection distance of the plate is processed 4-5 m for boneless concrete and 8-15m for boned concrete with bone. (Pd-T-14-2003), taken a distance of 5m. If the concrete plate is above 250 mm, then the diameter determination is using the Austrian Table 2010. Based on the 2010 Austroad plate thick, then the diameter of the concrete staple used is 32 mm, with a length of 45 cm and a distance of 40 cm (Based on Pd-T-14-2003). The extension of the execution of the fastening rod uses bone Ø12mm, 50 cm long, and 70 cm long.

2. Elongated Connection (Tie Bars)

Planned extension lengthwise with a distance of every 5 m. This elongated connection is equipped with a threaded rod with a minimum quality of BJTD–40 and a diameter of 16 mm. Based on Pd-T-14-2003 the distance of the fastening rod used is 70 cm. Therefore, the elongated connection (tie bar) used is D16 mm long and 70 cm long, and the distance between the bones is 70 cm

3. Manual Analysis

In manual derivation analysis, *Meyerhoff's equation* (1965) is used in the following equation:

$$S_i = \frac{6q}{N}\left(\frac{B}{B+1}\right)^2 \quad (5)$$

In the analysis of load intensity applied in kip / ft2 = 0.49 kg / cm2, concrete width (ft) 30.48 cm, the analysis is carried out by giving loading variations as in the TABLE 5.

Table 5. Load combination

Load	Weight (kN/m²)	Weight (kip/ft²)
0 stacks container	15	0.31
1 stacks container	31.38	0.65
2 stacks container	47.36	0.99
3 stacks container	73.84	1.54

If the number of strokes on the SPT test is obtained 33 then the decrease that occurs is

$$S_i = \frac{6q}{33}\left(\frac{39.4}{39.4+1}\right)^2 = \frac{6q}{33} \times 0.95 = \frac{6q}{33} \times 0.95 = 0.17\,q$$

Analysis of Settlement

From the results of plaxis analysis obtained a total displacement of 2.5 mm. It can be seen in Figure 2.

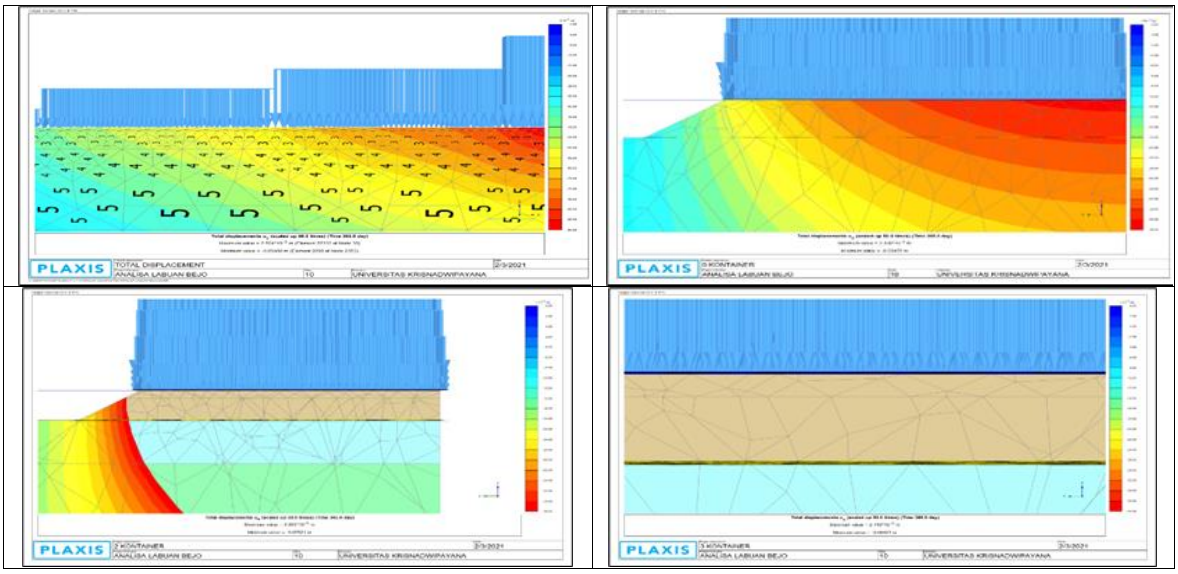

Figure 2. Analysis pf settlement with plaxis

With the above formula and the results of the analysis using PLAXIS, the results are shown in Table 4.

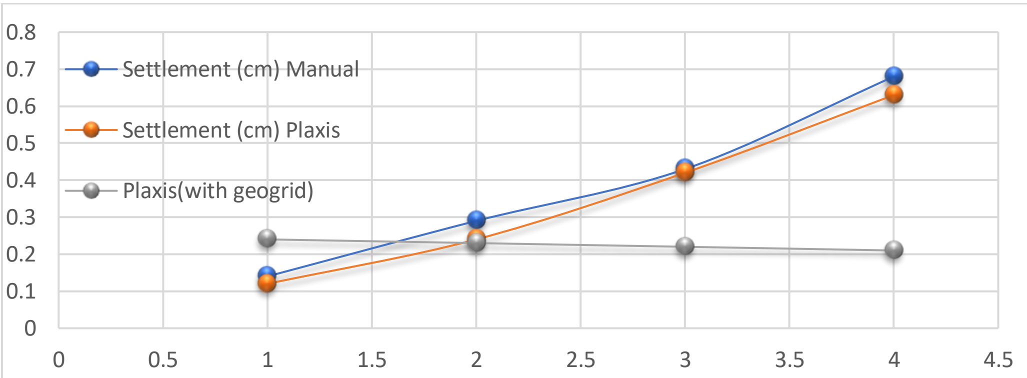

Figure 3. Settlement with combination

From the results of Figure 3, it can be seen that the decrease occurs with no conditions, namely the decrease with manual calculations with calculations using plastic software. The calculation of soil subsidence with the help of Plaxis 3D is made in 2 conditions, namely the real condition of the original soil (condition 1), without geogrid (condition 2), and with the addition of geogrids to the soil (condition 3). The analysis was carried out with a combination of loads from 0 containers to 3 containers with the addition of a reach stalker [5].

The decrease that occurs per year in container conditions at conditions 1 from 0 containers to the accumulation of 3 containers is obtained by an increase in land subsidence from 0.14 cm, 0.29cm, 0.43 cm to 0.68 cm. As for condition 2, the decline that occurs is no different from the first condition. Land subsidence is increasing singing with the addition of containers, namely from 0.12 cm, 0.24 cm, 0.42 cm, and 0.63 cm.

And in condition 3 the magnitude of land subsidence decreases along with the addition of container loads. Deterioration in conditions to two on 0 containers to 3 stacks of containers of 0.24 cm, 0.23 cm, 0.22 cm, and 0.21 cm.

The addition of geogrids to the soil is proven to reduce land subsidence due to container loads and reach stalkers [5].

Conclusion

A concrete slab thickness of 35 cm with a concrete quality of K350 equivalent to fc' 29.7 MPa is obtained based on the findings of the calculation analysis performed using the AASHTO method for the thickness of the concrete slab that can withstand a reach stacker of 71.8 tons and a maximum load container of 6 tons / m2. A 35 cm thick concrete slab with a K350 concrete quality, or fc' 29.7 MPa, is achieved. According to the findings of the land subsidence analysis conducted with the assistance of the PLAXIS 3D application program to withstand the load of the reach stackers and container, the loading is made intermittent by using geogrid to reinforce the land subsidence; the maximum decrease is 0.21 cm, and the manual calculation shows a decrease of 0.68 cm annually. deemed safe to sustain the weight above it. As per SNI 8460: 2017 regulations, permits must decline by less than 15 cm + B / 600 annually

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