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Concrete Slab Pavement Behavior On Expansive Soil At Swell Condition Using Finite Element Method Analysis

***Wibowo[1], Ary Setyawan[2], Yusep Muslih P[3], Bambang Setiawan[4], and Bagas Chairum Marcel [5]**

[1]Engineering Faculty, Universitas Sebelas Maret, Indonesia; [2,3,4,5] Universitas Sebelas Maret, Indonesia
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ABSTRACT: Expansive soils occur a significant volume change when there is a change in water content. This study aims to determine the behavior of rigid pavement on expansive soil using finite element method, consists of laboratory test using a semi-3D box and finite element method analysis with SAP2000. The data used are primary and secondary data also data determined from standard or based on previous research. Modulus of subgrade reaction of soil was obtained through trial results from laboratory tests, which was 13.000 kN/m3, equivalent to CBR value of 1.5%. The maximum swelling pressure from the oedometer test is 175 kPa. Considering the location of soil sampling, the thickness of the concrete slab was chosen 18 cm, 20 cm, and 25 cm with axle-load centralized 8 tons for collector road, with 4 loading positions. The results of this study indicate that the largest deflection (lendutan) occurs in a plate with a thickness of 18 cm and the loading conditions at the edge-corner of the plate. The thicker plate, the deflection is smaller, and vice versa.

Keywords: Expansive soil, Swelling, Rigid pavement, finite element method

1. INTRODUCTION

Expansive soils have a high potential for shrinkage in case of changes in moisture content. This property is associated with clay mineral levels in particular montmorillonite and illite. When clay mineral levels rise, then the surface area and liquid limit and plasticity index increase, so that the potential for shrinkage will rise [1]. The degree of development depends on several factors, such as the mineral content of clays, the specific area of clay, the composition of the soil, the initial moisture content and so on [2].

On road pavements, the edges of the pavement that hit the ground will rise during the rainy season and move down when it is summer. In addition, the movement up and down the base soil (subgrade), generally begins at the edge of the pavement, where this part of the groundwater content is strongly affected by rainwater. and drying due to sunlight. Pavements located on expansive soils often require special handling to cope with the factor of soil shrinkage. Rigid pavement is one of the alternatives to expansive above-ground roads due to its own heavy factors that are able to withstand soil development[3],[4].

Failure of rigid pavement to maintain the ability of its service before ending as planned due to the damage of rigid pavement plates initiated by small cracks continued cracking growth due to repeated loads and excessive loads that cause road damage. Cracks that occur caused by strain occur beyond the allowable elastic strain limit of the concrete material caused by the deflection that occurs. The position of the load point also affects the occurrence of deflection and it has consequences for the bending behavior of structural elements in this case is a rigid pavement plate [5], [6], [7].

The position of the load at the center and edge of the plate, exerts an influence on the deflection, moment, and latitude force that occurs on the concrete plate. The estimated load at the edges results in a greater value than the position of the load in the middle with a difference of 100% to 150%. In addition, the thickness of the concrete plate also affects the deflection and tensile voltage that occurs, the thicker the plate, the smaller the deflection and tensile voltage that occurs. The thickness of the concrete plate affects its rigidity, so the thicker the deflection the smaller. The rigid pavement structure design for thickness variations of 10 cm and 15 cm has a tensile voltage that exceeds the permit limit so it is considered unfit. Thickness values that meet the permission limits of 20 cm, 25 cm, and 30 cm [8], [9], [10]

Rigid pavement slab behavior is not easily modeled in laboratory testing, for which the numerical method approach is the best alternative to obtaining illustrations of pavement slab behavior. rigid especially those affected by the expansionary soil subgrade. The most popular numerical method is the element up method. The concept of this method is to divide the analyzed object into several small parts/elements by the number up. The accuracy of elemental methods is close to 99% of validation to testing in the laboratory [11], [12],[13].

The purpose of this study is to find out the behavior of expansionary soil development on box test which will be used as a basis for modeling on field scale analysis and find out the influence of expansive soils. stiff pavement due to vehicle load during maximum development. There are two analytical models, namely laboratory scale analysis and field scale analysis.

2. METHOD

2.1 Testing Laboratory

Research is preceded by preliminary testing in the form of soil properties index tests. The main test is two tests, namely, using a Semi-3D box measuring 70 cm x 50 cm x 10 cm and analysis using the element up method. This main test is intended to determine the deflection and development of the soil when the soil is gradually moistened on the semi-3D dimensional box and know the deflection on the field scale plate and laboratory scale analysis methods of elements up to. Laboratory-scale testing uses steel plates measuring 45 cm x 20.5 cm x 0.2 cm. Expansive soil placed on the box up to 6 cm high. Gravel on the model serves as drainage, where water is first flowed. A sketch of laboratory testing can be seen in Figure 2. next

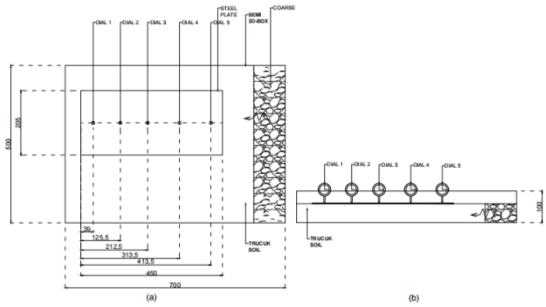

Fig 2. Laboratory-scale test sketch, (a) top view, (b) side view

Fig 3.Test model using semi-3D box

The lendutan pattern that occurs on the first day is that the side of the plate closest to the starting place of the flowing water undergoes greater lifting. Laboratory-scale test results show that the soil begins to expand starting from where the first time the water flows. The practice, if in the field is located on the side of the road that receives rainwater. More and more days, dial 2 to dial 5 began to change, meaning that the ground in that part has undergone development, at the same time dial 1 has begun to experience decline.

2.2 Analysis of Element Methods Up to

Analysis of element methods to be carried out two stages, namely laboratory scale analysis and field scale analysis. The initial stage in creating a model is to determine the dimensions and system of units used. The dimensions of the steel plate model correspond to the model on the 3D semi box test which is 45 cm x 20.5 cm x 0.2 cm. Maximum swelling pressure based on its maximum value (oedometer test result) which is 175 kPa is modeled with the surface load area with the direction from under the concrete plate (Figure 4). The 2nd analysis uses a field scale model. The part of the model that undergoes significant changes is on the part of the plate that receives the load, the mesh is made smaller to improve accuracy.

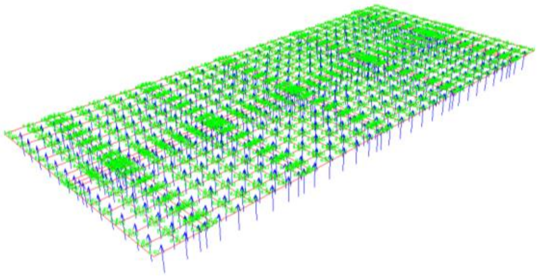

Fig 4. Model swelling pressure

The thick variations of the pavement plate used are 18 cm, 20 cm, and 25 cm (Figure 5) with additional variations of 4 different loading positions.

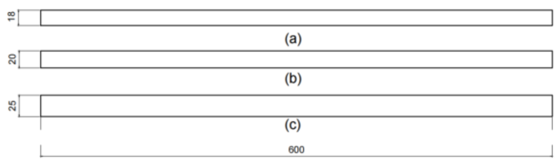

Fig 5. Plate thickness variations

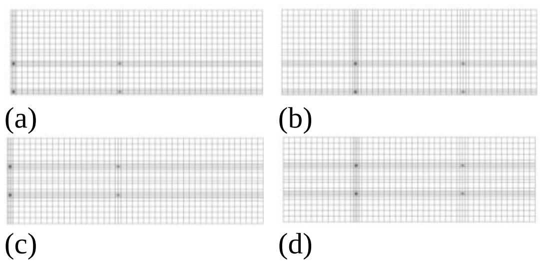

Fig 6. Loading position (a) Edge 1, (b) Edge 2, (c) Center 1, dan (d) Center 2

Figure 6 (a) shows the end-corner loading position, (b) the loading location at the edge but is in the middle, (c) the vehicle load is in the middle of the plate end, and (d) the load is right in the middle of the concrete plate. The variations to be used in this study can be seen in Table 1 Below,

Table 1. Variations in the behavior of concrete plates

Type of variation	Load	Plate thickness (cm)
1	Edge 1	18
		20
		25
2	Edge 2	18
		20
		25
3	Center 1	18
		20
		25
4	Center 2	18
		20
		25

3. RESULT AND DISCUSSION

The results of the lendutan on the third day of the laboratory test are then entered into the graph to determine the maximum deflection by looking at the trend on the chart. Table 2 shows the swelling value on the 3rd day with maximum development on him l.1.

Table 2.Maximum swelling on day 3. 2

Day To-	Swelling Max Dial	Dial (div) any distance from the far side **of the** plate (mm)				
		39	125.5	212.5	313.5	413.5
3.2	1	2.10	4.30	8.30	11.50	13.30

The value of steel plate lendutan results of laboratory-scale MEH analysis can be seen in table 3 below,

Table 3. Maximum development value of observation and analysis of Element Method Up

Dial	Distance (mm)	Lendutan observations (mm)	Lendutan MEH analysis (mm)	Swelling pressure (kPa)
5	39	2,10	2,25	27,63
4	125.5	4,30	5,11	56,58
3	212.5	8,30	8,47	109,21
2	313.5	11.50	11.59	151.32
1	413.5	13.30	13.49	175.00

The value of the comparison of the results of laboratory observations and the results of MEH analysis can be seen in Figure 7. The lendutan value of the MEH analysis results show a result close to the laboratory test value after entering a k $_{v}$ value of 13,000 kN / m^3.

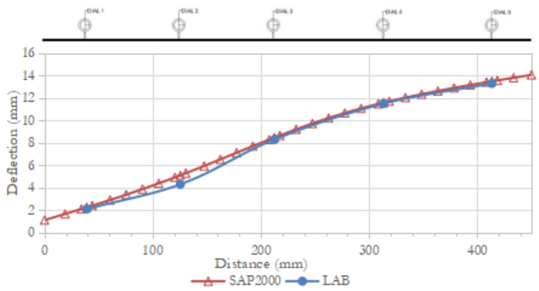

Fig 7. Comparison of MEH analysis lendutan with laboratory scale transverse pieces

3.1 Analysis before swelling

Rigid pavement structure model with loading located in four positions, supported by soil with a subgrade reaction coefficient (k_v) of 13000 kN/m3 taken from a CBR value of 1.5%. The results of the analysis of the element method up to which will be displayed in the form of lendutan at the concession before development and during development[14] The graph of each lendutan is taken pieces transversely and elongated. The results are used to determine the behavior of concrete plates based on variations in the position of the load and thickness of the concrete plate. [15]

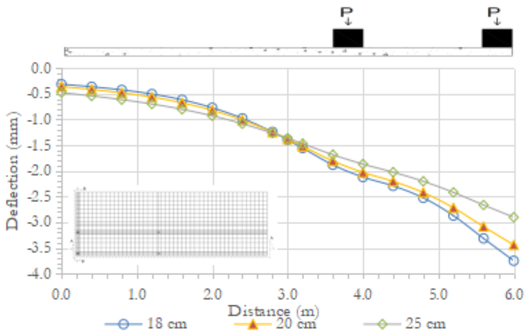

Fig 8. Lendutan before development due to transverse 1st edge loading

Figure 8. indicates the relationship of the lendutan value that occurs on the plate due to the loading of edge 1. The maximum lendability values on plates of 18 cm, 20 cm, and 25 cm respectively are -3,752 mm, -3,444 mm, and -2,904 mm.

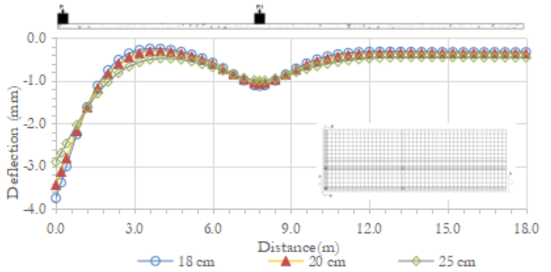

Fig 9. Lendutan before development due to loading edge 1 elongated

Figure 9. shows a graph of the lendutan value on the plate due to the loading of edge 1 elongated. Concrete slabs of 18 cm, 20 cm, and 25 cm respectively have lent of -3,752 mm, -3,444 mm, and -2,904 mm. The value of concrete plate softening of each type of loading before further development can be seen in Table 4.

Lendutan results show that the deflection in an elongated direction with the configuration of the elongated directional edge load produces maximum deflection, to overcome this is usually installed dowel reinforcement so that There is a load transfer between one plate and the next plate, thus it will be reduced to a large deflection so that the plate can avoid damage. [16],[17],[18]

Table 4. Plate deflection recapitulation before development

Place Load	Plate **Thickness** (cm)	Transverse Maximum review **points**	Elongated Maximum review **points**	maximum
		mm		
Edge 1	18	-3,752	-3,752	-3,752
	20	-3,444	-3,444	-3,444
	25	-2,904	-2,904	-2,904
Edge 2	18	-2,854	-2,624	-2,854
	20	-2,610	-2,421	-2,610
	25	-2,213	-2,085	-2,213
Middle 1	18	-3,335	-3,650	-3,747
	20	-3,145	-3,395	-3,496
	25	-2,793	-2,944	-3,047
Middle 2	18	-1,390	-1,379	-1,396
	20	-1,320	-1,301	-1,320
	25	-1,214	-1,190	-1,214

3.2 Analysis with loading and swelling

Lendutan at the time of development has a positive value due to the influence of higher swelling pressure compared to the weight of the vehicle load. Figure 10. shows a graph of the value of the lendutan on the plate during development due to the loading of the 1 transverse edge. The maximum deflection occurring due to the influence of the rear wheels respectively on the concrete slabs of 18 cm, 20 cm, and 25 cm is 13,672 mm, 13,181 mm, and 11,894 mm.

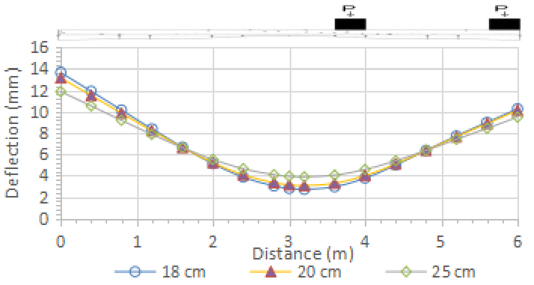

Fig 10. Lendutan during development due to transverse 1st edge loading

Figure 11. shows a graph of the lendutan value on the plate during development due to the loading of edge 1 elongated. The maximum yield of the selected sections respectively on concrete slabs of 18 cm, 20 cm, and 25 cm is 13,907 mm, 13,425 mm, and 12,198 mm.

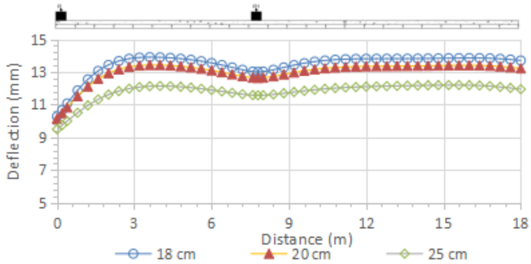

Fig 11. Deflection during development due to loading edge 1 lengthwise

The value of concrete plate softening of the condition of each loading during the development of the cell is also designed into table 5 below:

Table 5. Condition of each loading during the development of the cell

Place Load	Plate **Thickness** (cm)	Transverse: Maximum review **points**	Elongated: Maximum review **points**	maximum
		mm		
Edge 1	18	13,672	13,907	13,907
	20	13,181	13,425	13,475
	25	11,894	12,198	12,310
Edge 2	18	13,826	13,019	13,862
	20	13,379	12,587	13,413
	25	12,186	11,455	12,235
Middle 1	18	12,986	6,017	14,211
	20	12,407	6,142	13,741
	25	10,990	6,454	12,469
Middle 2	18	13,639	5,930	13,913
	20	13,148	6,047	13,455
	25	11,883	6,353	12,211

Rigid pavement behavior based on the results of the analysis has the same conclusions as previous studies. The thickness of the plate and the position of the loading affect the value of the lendutan. The thicker the plate, the smaller the lendutan and vice versa and the largest lendutan occurs in the position of the load at the end of the plate. The transverse deflection of the curve of the edge is greater than that of the middle loading. [11], [5]

Table 6. Difference in the results of laboratory observations and analysis of element methods up to (FMA)

No.	Lendutan (mm): Distance	Lendutan (mm): Observation	Lendutan (mm): FMA	Difference

1	39	2.1	2.25	6.66%
2	125.5	4.3	5.11	15.78%
3	212.5	8.3	8.47	2.01%
4	313.5	11.5	11.59	0.76%
5	413.5	13.3	13.49	1.38%

The results of the analysis of the method of elements up to and laboratory tests (Figure 7) also showed results that did not differ much from 0.76% to 15.78%. [6], [19]. These results show that the effect of swelling does not reach the farthest part of the source of water exposure, but at the time of numerical analysis is still taken into account variable swelling so that the magnitude The deflection is slightly different from the measurement results in the laboratory [20].

4. CONCLUSION

The behavior of rigid pavement plates above expansive soils is significantly influenced by the characteristics of the shrinkage of such expansive soils.

The deflection of the rigid pavement plate is also affected by its thickness, because the thicker the plate, the heavier and stiffer it is so that it can reduce deflection due to swelling.

Differences in numerical analysis using the element method up to measurements in the laboratory below 0.1 mm or 2%, except on the side of the plate far from water exposure there is a difference. It was 15.78%. This is because the effect of swelling in real terms does not occur at the designated time span, but numerically the influence of swelling is still taken into account.

The relatively large difference in the farthest part of the water exposure, so the influence of water does not reach in that part resulting in expansive soil is not affected by swelling.

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