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Analysis of Continuous Slab Foundation as a Sub Structure: Teluk Bayur Mini Olympic Stadium, East Borneo Indonesia

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Preface: 2nd International Conference on Technology, Informatics, and Engineering

22 The International Conference on Technology, Informatics, and Engineering (ICon-TINE) is an annual scientific conference organized by the Engineering Faculty, University of Muhammadiyah Malang. In 2nd ICon-TINE 2022, this conference was held Hybrid Conference with attracts both in-person attendees/face-to-face and virtual/online attendees via Video Conference (for the keynote speaker) and record presentation for the invited presenter and presenter. More than 140 papers have been submitted from various research and educational institutions around the world (India, Indonesia, Taiwan, and Malaysia). The advancement of technological approaches and engineering methods may simplify the existing problems from previous findings. The original notions from the researcher may inspire the other experts to develop, modify, or even combine the proposed method with the existing method for resulting in more efficient procedures. Therefore, Icon-TINE aims to provide a platform for researchers, scholars, and practitioners to discuss and present their latest findings corresponding to their field of expertise. This conference provides opportunities for the delegates to exchange new ideas face-to-face to bring together leading academic scientists, researchers, and research scholars to exchange and share their experiences and research results on all aspects of engineering, science, and technology. We hope that the conference results will lead to significant contributions to the knowledge in these up-to-date scientific fields.

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Analysis of continuous slab foundation as a sub structure: Teluk Bayur Mini Olympic Stadium, East Borneo Indonesia

FREE

Aulia Indira Kumalasari ✉; Moh. Abduh; Dwi Aziz Wicaksono; Yunan Rusdianto

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Analysis of Continuous Slab Foundation as a Sub Structure: Teluk Bayur Mini Olympic Stadium, East Borneo Indonesia

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1

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Abstract. The construction of Teluk Bayur Mini Olympic Stadium, which is located in Teluk Bayur, East Borneo, Indonesia is planned to support of sport competition activities which will be held in 2022. The existing condition the stadium only has a tribune on the east side. However, because there are soil investigation data on the west side area, the authors are interested in conducting an analysis related to the construction of the substructure on the West Tribune using a Continuous Plate foundation. The drill logs data, N-SPT>50 was obtained at a depth of 2 m. The west tribune is planned to be 22 m wide and 115 m long. The biggest load that acted is 3192.26 kN on grid 11 segment 2. From this load, the foundation is planned to be 2 m wide and 0.8 m thick. The length of the foundation itself is divided into 2 types, namely, P1 with 24 m and P2 with 25 m. After that, the smaller soil bearing capacity (qa) is obtained at 598.8 $\mathbf{kg\,.\,cm^{-2}}$ on type P1. The reinforcement number of P1 in the longitudinal direction is D25-150 and D25-200, in the support area it is D25-150 and D25-100. In the transverse direction, the requirements for foundation reinforcement of type P1 are D19-200 and D19-100. Because this study only uses one location for the drill log point, for future research it is necessary to carry out further ground investigations to be safer in further planning.

Keywords: Foundation, continuous plate, drill log, N-SPT

INTRODUCTION

Teluk Bayur Mini Olympic Stadium is the largest stadium in Berau, East Borneo, Indonesia. This stadium is planned to support the activities of the Provincial Sports Week in 2022. The stadium is planned to have a grandstand with a capacity of 3000 people equipped with other supporting facilities where these facilities prioritize comfort for athletes and the audience. The length of the Tribune is 115 m and 22 m wide which will be divided into 3 segments. This building needs sub-structure planning that is supported by a strong foundation. The foundation is the lower structure of a building that acts as the load-bearer of the superstructure. Foundation transfer the load calculated from the superstructure to the ground safely. A well-built foundation is a must for a building because various of foundation type is dependent on the loads and the type of the soil.

When designing a structure of a building, it is necessary to select a suitable foundation, which is proper in terms of cost and statics [1]. In the sub-structure of the West Tribune, they chose a continuous foundation as part of the sub-structure, where the foundation is a shallow foundation type. The shallow foundation has a depth of Df/B is 1. This selection was based on several factors including the upper layer data on the soil which tends to be a silt-clay type with a layer depth of 1 m. The soil is included in the classification of undisturbed soil conditions where this type of soil can result in severe land subsidence. In contrast to soft soil which has a small bearing capacity and a large settlement [2].

The second layer is a type of claystone soil. On the results of soil checks, hard soil layers were obtained at a depth of 2 m to a depth of 20 m. From the drill log data at point B.01 with a Standard Penetration value (N-SPT > 50) and

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CPT data at point S.03, the hard soil depth number is 1.80 m with a cone resistance value of 204.69 $kg.cm^{-2}$. If the planning results in a small bearing capacity value and a large settlement, it is necessary to improve the soil such as by adding geotextiles or bamboo grid [3].

METHODS

In this study use several methods to plan the foundation in accordance with the specifications of the planned building. The first method is data collection. In order to support the planning process, initial data is needed. The data that has been obtained and will be used in planning is in the form of structural data, soil investigation data, and earthquake area data. In addition, data as previously mentioned, is also used other data where the data is obtained from various kinds of literature such as journals, books, or websites. These data can be classified based on how they are obtained and are divided into two types of data, namely primary data and secondary data. The second method is structural analysis including superstructure, foundation dimension planning, soil calculation including soil bearing capacity, stresses under the foundation, and foundation settlement. While the last method is the calculation of reinforcement on a continuous foundation.

RESULTS AND DISCUSSION

SUPERSTRUCTURE MODELLING

The modeling on the West Tribune of the Teluk Bayur Mini Olympic Stadium was carried out using computational structure analysis. In this modeling, there is a change in the structure where the modeling does not review the structure of the roof truss. The tribune structure consists of 3 segments, therefore the modeling of the structure is also divided into 3 separate parts, in which case, segments 1 and 3 have the same structure so it is sufficient to model only one segment of them. The modeling of the structure can be seen in **FIGURES 1 (a)** and **(b).** Superstructure modeling is carried out to find the largest reaction on the structure that will be used to design continuous slab foundations [4]. In addition, Superstructure modeling is also used to make it easier to find out the forces that work according to the combination. The modeling in segments 1 and 2 is shown in **FIGURES 1 a** and **b**. The loads acting on the tribune include dead loads which are the weight of the entire building; live loads, which are loads that come from the use of a tribune, and earthquake loads which are action loads that occur due to the presence of lateral forces.

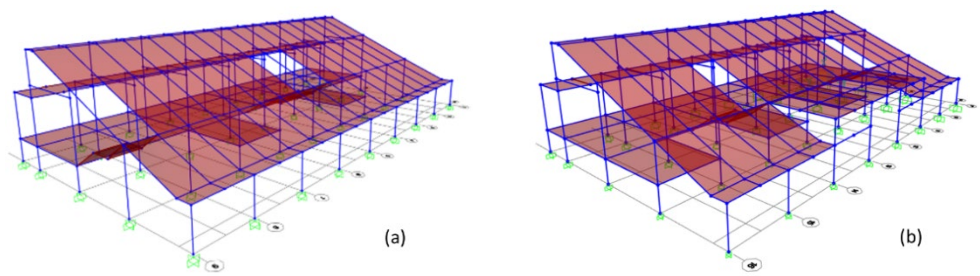

FIGURE 1. Modeling; (a) segment 1 and (b) segment 3

The results of the modeling obtained the forces that work on the structure of the Tribune. These forces will be used in the enumeration related to the selection of sub-base structure dimensions. The largest Fz reaction value is obtained from the combination 2. This load combination is the result of calculations between dead loads, live loads, and earthquake loads acting on the structure. The Fz value obtained from the modeling analysis is shown in **TABLE 1**.

TABLE 1. The reaction force acting on the structure

Segment	Grid	Joint Label	Fz (kN)
2	11	470	704,423
		472	327,823
		474	216,477
		475	823,187
		476	1120,35
	Total		3192,26

DIMENSIONAL DESIGN OF CONTINUOUS SLAB FOUNDATION

In determining the dimensions of the plate, the value of the resultant must be obtained first by calculating the moments acting at the center of the column. The moment itself is obtained from the multiplication of the force acting with the distance between the load and the reference point. **FIGURE 2** shows an illustration of the load acting on the column.

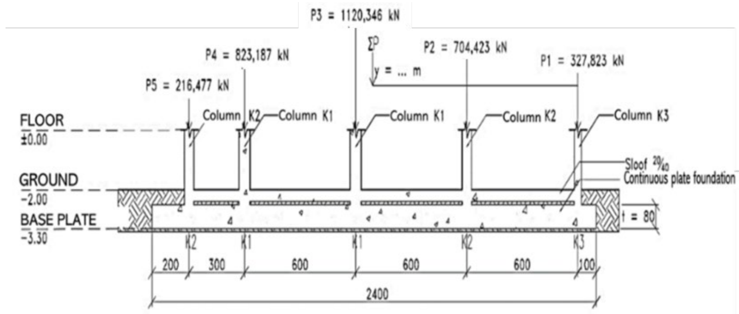

FIGURE 2. Load acting on the column

Determination of the dimensions of the foundation is carried out by calculating the load acting on the slab, then the load will be used to determine the length of the slab. Then the next step is to determine the dimensions of the width of the foundation. The equation to find the resultant loads from the center of the column is through the calculation in **Equation (1)**. While the length of the foundation is obtained from **Equation (2)**

$$\sum P\ y = (P2xL1) + (P3xL2) + (P4xL3) + (P5xL4) \quad (1)$$

$$L = 2y \quad (2)$$

From the results of calculations based on **Equation 1**, the distance (y) calculated from the center of P1 is 11.60 m, so the length of the foundation calculated by **Equation 2** is 23.2 m. The results of these calculations can then be rounded up to 24 m to simplify further calculations. The recapitulation of the calculation results on other segments
8 shows that the dimensions of the foundation can be divided into two types, P1 with a length (L) of 24 m and P2 with a length (L) of 25 m. Based on these dimensions, the width for each type of foundation (B) can be determined using **Equation (3)** with the allowable bearing capacity (qa) obtained from laboratory testing of 228.858 kN/m^2.

$$B = \frac{\Sigma P}{Lq_a} \quad (3)$$

From this equation, the width of the foundation (B) is 0.58 m wide. However, because the largest column
24 dimension used in the analysis is 0.6 m x 0.6 m and the column position is located in the middle of the foundation, only 0 mm is left from the edge of the column to the edge of the foundation. This will make it difficult to control the thickness of the foundation against shear forces. Therefore, the assumption of the thickness of the foundation is chosen as 800 mm.

BEARING CAPACITY

21 The bearing capacity of the soil can be defined as the maximum ability of the soil to withstand the compressive forces of the superstructure without failure [5]. Bearing capacity of the soil is expected to be able to support the foundation structure. Bearing capacity is expected to be able to carry the load of the structure, so that the foundation can bear a land settlement which is still within the tolerance limit [6] [7]. The analysis of the bearing capacity of continuous slab foundations uses general equations that are often used in shallow foundations, such as, the equations
4 of the Terzaghi (1943), Mayerhof (1955), and Mandel and Salencon (1969) [8]. To analyze the bearing capacity of
14 rectangular foundations based on the Terzaghi (1943) using the **Equation 4**, while the analysis of the bearing capacity of the foundation based on the Mayerhof (1955) uses the **Equation 5**.

9
$$q_u = cN_c(1 + 0{,}3B/L) + p_oN_q + 0{,}5\gamma BN_\gamma(1 - 0{,}2B/L) \quad (4)$$

10
$$q_u = s_cd_ci_ccN_c + s_qd_qi_qp_oN_q + s_\gamma d_\gamma i_\gamma 0{,}5\ B'\gamma N_\gamma \quad (5)$$

6 Bearing capacity factor by Terzhagi and Mayerhof are obtained based on the relationship between the friction
6 angle with N_c, N_q, N_γ [9]. The graph used for both methods are as shown in **FIGURE 3**. Based on the graph of Figure

Terzhagi and Mayerhof, *it is found that the bearing capacity factors of Terzaghi are Nc = 40.5; Nq= 25.5; Nγ = 24, while the bearing capacity factor by Mayerhof* N_c *= 32,5;* N_q *= 19;* N_γ *= 21.*

In contrast to Terzhagi and Mayerhof who used graphs to determine the bearing capacity factor, Mandel and Salencon (1969) proposed **Equation 6** as an equation for calculating the bearing capacity of foundations in layered soils. This condition is supported by the bottom layer of the foundation in the form of infinitely hard soil.

$$q_u = \xi_c c N_c + \xi_q p_o N_q + \xi_\gamma 0{,}5\, B \gamma N_\gamma \qquad (6)$$

Mandel and Salencon used the Terzaghi bearing capacity factor and described the coefficient of Mandel and Salencon (1969) as $\xi_c = 5{,}81$; $\xi_q = 5{,}55$; $\xi_\gamma = 1{,}95$. The recapitulation of the soil bearing capacity by Terzaghi, Mayerhof, and Mandel and Salencon as shown in the **TABLE 2, 3**, and **4**

TABLE 2. The results of the Pu based on the Terzhagi method

Type	Gr	Dimension (m)		A (m2)	qn (kN/m2)	qs (kN/m2)	Pmax (Kn)	Pu (kN)
		B	L					
P1	12	2	24	48	1797,62	623,88	29945,99	2620,56
P2	5	2	25	50	1815,87	629,96	31497,88	2527,22

TABLE 3. The results of the Pu based on the Mayerhof method

Type	A (m2)	D_f (m)	*Po* (kN/m²)	Mayerhof factors									q_{un} kN/m²	q_a kN/m²	P_{max} (kN)	P_u (kN)
				s_c	d_c	i_c	s_q	d_q	i_q	s_γ	d_γ	i_γ				
P1	48	1,30	24,67	1,05	1,23	1,00	1,03	1,11	1,00	1,03	1,11	1,00	1722,4	598,8	28741,9	2620,6
P2	50	1,30	24,67	1,05	1,23	1,00	1,02	1,11	1,00	1,02	1,11	1,00	1719,9	598,0	29897,8	2527,2

TABLE 4. The results of the Pu based on the Mandel dan Salencon method

TP	Gr	Dimension (m)			A (m²)	B/H	q_{un} (kN/m²)	q_a (kN/m2)	P_{max} (kN)	P_u (kN)
		B	L	T						
P1	11	2	24	0,8	48,0	2,86	8575,91	2883,30	138398,62	2714,89
P2	5	2	25	0,8	50,0	2,86	8575,91	2883,30	144165,23	2527,22

From **TABLES 2,3,** and **4**, the bearing capacity of the continuous slab foundation has met safety controls in all methods used. The succeeding expedience is to calculate the stress under the continuous slab foundation and calculate the settlement that occurs in the continuous slab foundation. The table above also shows that the Mayerhof method (1955) exhibits the results of the Pu with the smallest result. Therefore, the results of the analysis of this method will be used to control the further calculations.

STRESS UNDER FOUNDATION

The pressure under the foundation is said to be safe against the failure of the bearing capacity if the stress that occurs under the foundation is smaller than the allowable bearing capacity of the soil [10]. The equation for calculating the is expressed in **Equation 7**.

$$q = \frac{\Sigma P}{A} \pm \frac{\Sigma P e_y y}{I_{x'}} \pm \frac{\Sigma P e_x x}{I_{y'}} \qquad (7)$$

In this calculation, the parameters used are the load acting on the foundation, the eccentricity in the x and y directions, and the moment of inertia of the cross-section about the x and y axes. The location of the working load, the center of gravity of the cross-section, and the eccentricity are illustrated in **FIGURE 4**.

Ulrich (1995) stated that if the stress that occurs under the foundation (qu) is less than the allowable bearing capacity (qs) of the soil then the soil under the base of the continuous slab foundation is safe for designing the structure on above. The analysis exhibits that the stresses under the foundation in all types are declared safe against the failure of the bearing capacity, which is show in **TABLE 5**.

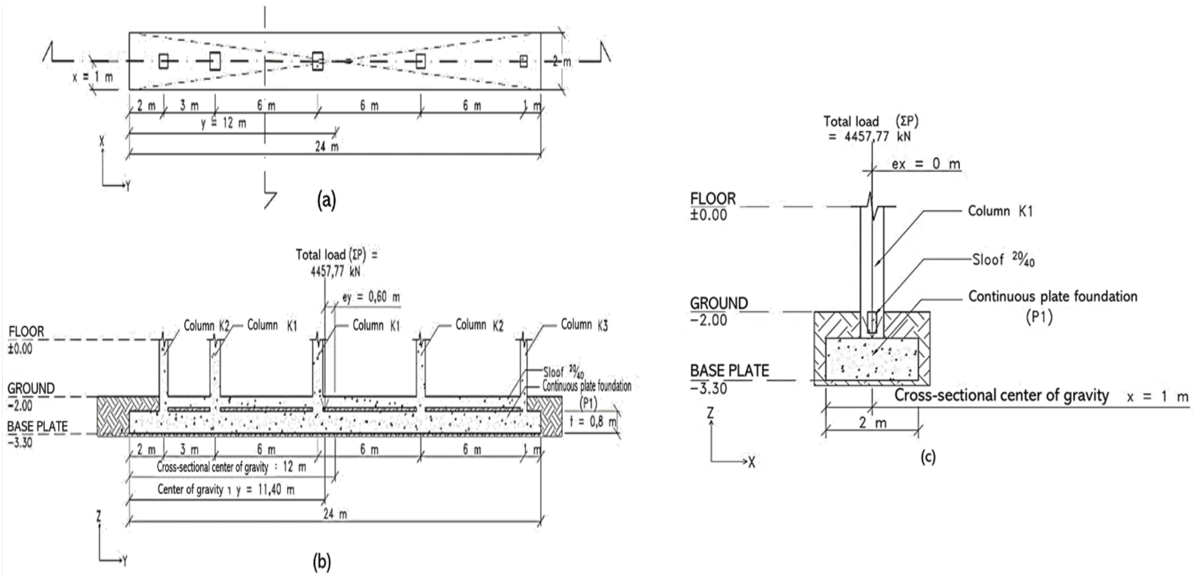

FIGURE 3. a) Top View of P1 (b) Y Cross Section of P1 (c) X Cross Section of P1

TABLE 5. Soil stress at the base of the foundation

Type	Load (kN)	Eccentricity (e) (m)		Ix	Iy	Soil Stress (kN/m2)		qu	qs
		x	y	(m^4)	m^4	Max	Min	kN/m^2	kN/m^2
P2	3172,48	0,00	0,90	16,67	2604,17	235,51	-108,61	235,51	597,96
P2	3958,20	0,00	0,92	16,67	2604,17	296,73	-138,40	296,73	597,96
P1	4230,25	0,00	1,03	16,00	2304,00	360,27	-184,01	360,27	598,79
P1	4232,16	0,00	1,00	16,00	2304,00	351,88	-175,54	351,88	598,79

After getting the results of the stress calculation on the soil, the calculation will proceed to an analysis of soil settlement and reinforcement that will be applied to the modeled foundation. Based on previous research, reinforcement on the foundation is able to reduce stresses that occur in the vertical direction [11].

CONTINUOUS PLATE FOUNDATION SETTLEMENT

Two criteria must be met if the designer wants to plan the foundation structure. The first criteria are that the soil under it must be able to support the foundation safely from shear failure, and the second is that the resulting settlement must be in accordance with the allowable settlement value [12]. The soil will experience compression if there is an added load on it. When there is compression, the soil will decrease on its surface. A land settlement is considered safe and does not cause damage to buildings if the settlement occurs uniformly, not excessively, and cannot be seen directly [13]. The soil layer in the construction of the Teluk Bayur Mini Olympic Stadium Tribune consists of a layer of silt clay and clay rock. The soil settlement that occurred was in the form of an immediate settlement and consolidation settlement. The settlement in the foundation is obtained by operating the results obtained from the calculation of immediate settlement and primary consolidation settlement [14, 15]. The equation used to find the immediate settlement of a continuous slab foundation is described in **Equation 8.** The results of calculations on immediate settlement and primary consolidation settlement can be seen in the **TABLE 6** and **7** respectively.

$$S_i = \frac{qB}{E}(1-\mu^2)I_p \tag{8}$$

TABLE 6. The results of calculations on immediate settlement

TP	Grid	q (kN/m2)	Dimension		L/B	Ip	Si (m)
			B (m)	L (m)			
P1	11	260,05	2	24	12	2,129	0,0673
P2	5	271,30	2	25	12,5	2,136	0,0703

TABLE 7. The result of Primary Consolidation Settlement

TP	Grid	P (kN)	Dimension		Df (m)	Po (kN/m^2)	Δ*p* (kn/m^2)	Sc (m)
			B (m)	L (m)				
P1	11	4457,77	2	24	1,3	24,669	77,902	0,0452
P2	5	4254,49	2	25	1,3	24,669	71,417	0,0431

Showers (1962) has determined the value of the maximum allowable settlement. The value of the settlement is 5 to 10 cm. In this analysis, the settlement that occurs is exhibits in **TABLE 8**. In the table, the value of the settlement is more than 10 cm. So that in the implementation it is necessary to improve the soil layers so that it can reduce the rate of land settlement. Based on previous research, an increase in the settlement rate can increase the value of the ultimate bearing capacity and increase the size of the foundation [16].

TABLE 8. Total Land Settlement

TP	Grid	Settlement		Total Settlement St (m)
		Si (m)	Sc (m)	
P1	11	0,0673	0,0452	0,1124
P2	5	0,0703	0,0431	0,1134

REINFORCEMENT OF CONTINUOUS PLATE FOUNDATION

Reinforcement in continuous plate foundations is calculated based on the maximum positive and negative moment reactions acting on each type of foundation due to the pressure between the column load and soil pressure. Continuous plate foundations are designed longitudinally or in the direction of the y-axis and transversely or in the direction of the x-axis. In designing the foundation in the direction of the y-axis, the design of reinforcement on the foundation will be like a reinforcement design on a continuous beam with soil stress as the load and the column as the support. As for the x-axis direction, the foundation will be designed like a footplate in general. The results of the calculation of foundation reinforcement as listed in **TABLE 9**

TABLE 9. The results of the calculation of foundation reinforcement

Parameter			**P1**	**P2**	**Parameter**			**P1**	**P2**
L (m)			24	25	Dowel overlap bar (mm)	K1		450	450
B (m)			2	2		K2		450	450
Thickness (m)			0,8	0,8		K3		400	400
					Longitudinal Reinforcement	Midspan	Tensile (upper)	D25-150	D25-150
Mu max (kNm)	Longitudinal	Mu max -	674,20	706,106			Compression (bottom)	D25-200	D25-200
		Mu max +	930,46	1220,85		Support	Compression (upper)	D25-150	D25-125
	Transversal	Mu max +	137,24	134,33			Tensile (bottom)	D25-100	D25-75
					Transversal Reinforcement	Compression (upper)		D19-200	D19-200
Dowel Bars	K1		10D16	10D16		Tensile (bottom)		D19-100	D19-100
	K2		8D16	8D16	Secondary bar	Longitudinal		D13-275	D13-275
	K3		8D13	8D13		Transversal		D13-275	D13-275

CONCLUSIONS

From the results and discussion, Continuous slab foundation with dimensions of width and thickness of 2 m, 0.8 m, and length of each type (P1 and P2) 24 m and 25 m is able to with stand the load received by the foundation of 3192.26 kN, where the results of the analysis exhibit that the load works on Grid 11 in segment 2. Base into two types based on its length. P1 with a length of 24 m is able to produce a bearing capacity of 598.79 kN.m^{-2}, while P2 which has a length of 25 m is able to produce a bearing capacity of 597.96 kN.m^{-2}. The reinforcement dimensions used in the longitudinal direction, if we consider the two types of foundations (P1 and P2), in the longitudinal direction of the field area, the required top reinforcement is D25-100, and for the beneath reinforcement, a dimension with a size of 25D-200 is required. The reinforcement on the support area, type P1 foundation requires D25-150 for the top reinforcement and D25-100 for the beneath reinforcement. For type P2, the foundation requires top reinforcement of D25-125 and beneath reinforcement of D25-75. All types of foundations (P1 and P2) in cross direction require D19-200 for the upper reinforcement and D19-100 for the bottom reinforcement. As well as the need for D13-275 as a secondary bar. The continuous plate foundation can be used as an alternative to the West Tribune with the sizes discussed in the study. However, further research still needs to be done in the future because this study only reviews based on one drill log point.

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