Alternative Solution for the Failure of Sheet Pile Structure at Barito River in Marabahan, Indonesia

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ABSTRACT
A sheet pile structure that was reinforced with concrete spun piles was constructed in 2005 in order to act as a road widening and riverbank protection for Barito river. The structure is comprises of 12 m long concrete sheet pile combined with concrete pile having a diameter of 60 cm and length of 36 m. During the early filling for the road widening, however, landslide occurred and the structure collapsed. An alternative solution was therefore required.
Soil profile at the site consists of very soft to soft clay having a thickness of 25 – 28 m. This layer is under laid by medium clay and dense sand up to 35m below the ground surface. Finite Element analysis was performed by modeling soil as the Mohr-Coulomb elastic-plastic material and by modeling concrete sheet pile and pile as elastic-plastic beam elements. Calculation results showed that safety factor for existing condition before filling was 1.1. Filling for the road widening reduced safety factor to less than 1.0 and resulted in instability of river slope and failure of the structure. It was decided that the combination of concrete sheet pile and slab-on-pile structure was the optimum solution. With this solution, safety factor of the river slope was then increased to more than 1.25 as the minimum requirement.

ABSTRACT
Une structure en palplanches a été renforcée avec des fibres piles a été construit en 2005 afin d'agir comme un élargissement de la route et de la protection des rives de la rivière Barito. La structure est composée de 12 m de longueur de palplanches en béton combinés avec des tas d'un diamètre de 60 cm et la longueur de 36 m. Au début de remplissage de l'élargissement de la route, cependant, les glissements de terrain ont eu lieu et la structure s'est effondrée. Une autre solution a donc été nécessaire.
Profil du sol sur le site se compose de très doux à l'argile d'une épaisseur de 25 - 28 m. Cette couche est définie par le moyen d'argile et de sable dense jusqu'à 35 m sous la surface du sol. L'analyse des éléments finis a été réalisée par modélisation de sol comme la Mohr-Coulomb élastique en matière plastique et par la modélisation des palplanches et pieux comme élastique-plastique éléments de poutre. Calcul des résultats a montré que le facteur de sécurité pour la situation existante avant le remplissage a été de 1,1. Remplissage de l'élargissement de la route pour réduire le facteur de sécurité inférieur à 1,0 et a abouti à l'instabilité de la pente de la rivière et la défaillance de la structure. Il a été décidé que la combinaison de palplanches de béton et de la dalle sur pile structure la solution optimale. Avec cette solution, facteur de sécurité de la pente de la rivière était alors passée à plus de 1,25 comme l'exigence minimale.

Keywords : landslide, riverbank protection, concrete sheet pile, concrete spun pile, slab-on-pile, finite element method

1 INTRODUCTION

Marabahan city is the capital city of Barito Kuala Regency in South Kalimantan Province. Population and economy growth in this city has been significant as a commonly occurred at a river side of the city, and the growth was centered along the river side. The government has planned to upgrade its infrastructure at the river side of Barito river to support the economic growth. The existing soil condition along the river contains a very thick of very soft clay. Geotechnical engineering problems were encountered due to low bearing capacity of the soil, change of river morphology, and sedimentation and erosion of the river bed that endangered riverbank stability.

Until recently, actions for protection and reinforcement of the riverbank have been conducted especially to protect the road from landslides, by using Ulin wood sheet pile construction. In order to widen the road and reinforce the slope of Barito riverbank, hence in the year 2005 the riverbank slope construction was reinforced with 12 m long corrugated concrete sheet pile (CCSP) combined with concrete spun piles (CSP) with diameter 60 cm and length 36 m (Figure 1).

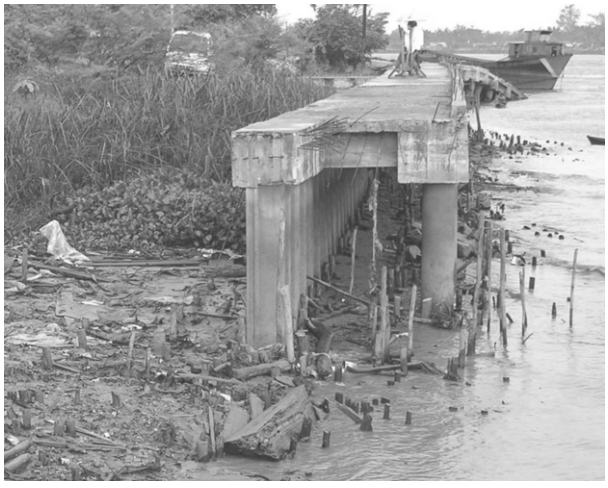

Figure 1. Road widening and riverbank protection using corrugated concrete sheet pile and concrete spun piles.

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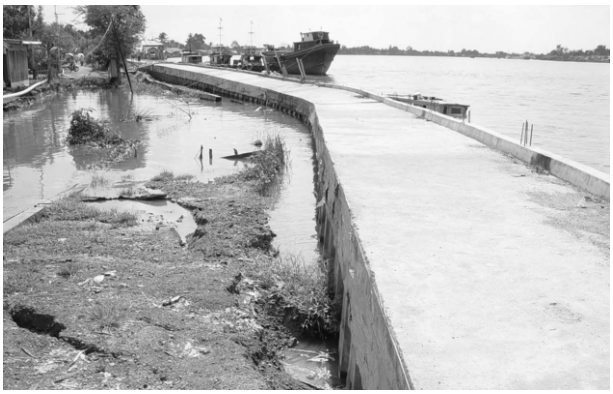
After executing this construction in August 2005, nevertheless, in the early filling for road widening, large landslide occurred at the riverbank and collapsing the structure that consisted of concrete corrugated sheet pile combined with deck on pile (Figure 2)



(a)

(b)

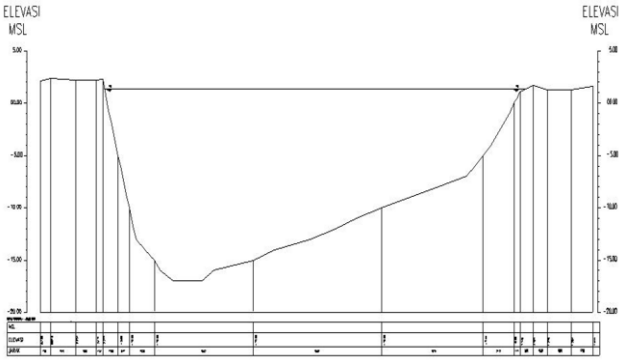
(c)

Figure 2. Landslide of riverbank followed by collapse of the structure consists along the riverbank of Barito river.

An alternative solution was therefore required to solve the above instability. The solution was used to replace the existing structure. It was designed to be able to carry loads from road widening and to reinforce riverbank stability along 1500 m of Barito riverside. The reinforcement was calculated by considering the soft soil condition, current characteristic, wave and river tidal.

2 BATHYMETRY AND SOIL CONDITIONS

Topographic and bathymetric survey was conducted to obtain geometry of the river. A typical example of river cross section is shown in Figure 3.



Figue 3. Typical example of river cross section.

Based on the results of soil investigation, generally the soil layers can be described as follows (Figure 4):

1. Soil Surface to a depth of 21 m consists of very soft clay with N-SPT values that range from 0 to 2
2. The next layer is soft to medium clay having a thickness of 11 m and N-SPT values of 2 to 9.
3. Below medium clay layer, medium dense clayey sand is observed. It has thickness of 4m and N-SPT values that vary from 10 to 20.
4. Dense to very dense sand with N-SPT > 20 is found at a depth of 37.0 m

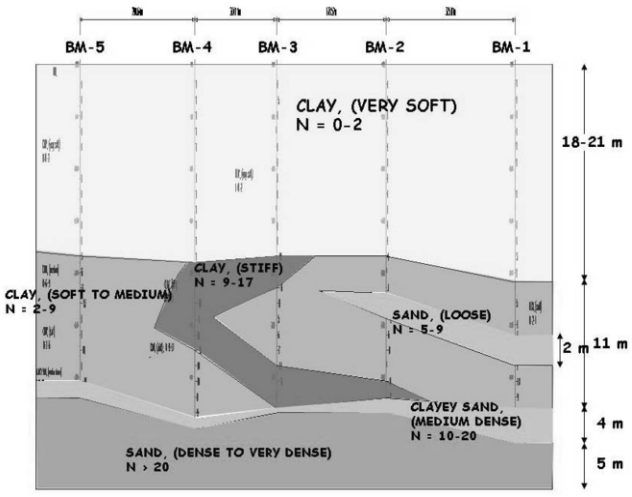


Figure 4. Soil condition of the site.

The values of shear strength and deformation of soils was estimated from the results of field and laboratory soil investigations based on Robertson dan Campanella (1983) and Sanglerat (1972) and presented in Table 1.

Layer No.	Identification	Unit Weight		Shear Strength		Stiffness	
		γ_d (kN/m³)	γ_w (kN/m³)	c_u kPa	ϕ (°)	Eu (kPa)	ν
1	Surface Layer	17.5	17.5	50.0	5.0	10000.0	0.30
2	Very Soft Clay	16.0	17.0	15.0	-	3000.0	0.35
3	Soft Clay	16.0	17.0	25.0	-	4000.0	0.34
4	Medium Clay	16.0	17.5	45.0	5.0	9000.0	0.33
5	Stiff Clay	17.5	17.5	100.0	5.0	20000.0	0.30
6	Dense Sand	18.0	18.0	1.0	38.0	50000.0	0.30

Tabel 1. Estimated soil shear strength and deformation parameters

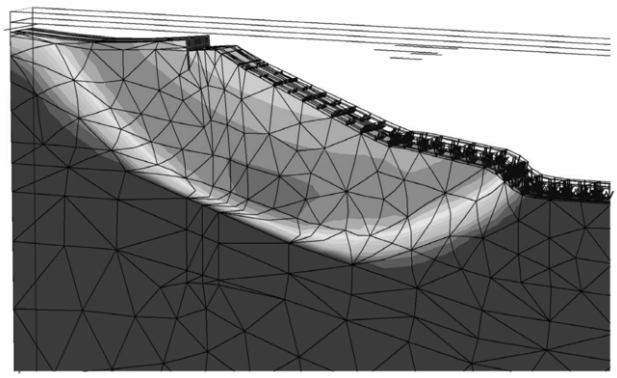


Figure 5. Result of slope stability analysis for existing riverbank condition before filling (SF = 1.1).

3. ANALYSIS

Finite Element Method was used to analyze the slope stability by assuming soil as the Mohr-Coulomb elastic-plastic material, modeling pile and sheet pile as elastic-plastic beam element, and by using Plaxis 3-D.

Existing condition

Analysis of slope stability was conducted for the existing condition before soil filling. The safety factor for riverbank that was reinforced by sheet pile and pile structure was 1.1. Filling of 05-1.0 m soil decreased the safety factor to less than 1.0 and resulted in failure of slope and collapse of the structure (Figure 5).

Proposed solution

Construction of reinforced Riverbank of Barito River must be designed to restrains landslides and also accommodates the requirement area at the riverbank, that still fulfill those requirement criteria. The selection of the riverbank type must also consider the existing of natural slope stability. The structure is in the form of combination sheet pile and deck on pile construction. By using this construction, the requirement of area development can be fulfilled without backfill, thus it would be effective for river bank area at soft soil condition. This type has advantage in the realization and the construction cost is relatively economic.

By using this system, vertical load as a consequence of overburden and life load will be transferred to the hard soil pass through pile foundation. So that the critical of natural slope with minimum safety factor are not influenced by the vertical load.
Based on the explanation above, type of reinforcement that suitable for soil condition along the river bank of Barito River is the combination of sheet pile and deck on pile construction (see Figure 6). Estimation factor to design deck on pile are diameter selection and distance between pile spaces, so that it can find stiff enough construction to:

- prevent big lateral deformation
- avoid bending of the pile caused by vertical load

Global of slope stability was observed by Plaxis 3D based on cross section of the riverbank that experienced landslides. From the results above can be known the level of safety of the riverbank after construction fulfill the design criteria (SF >1.25), see Figure 7.

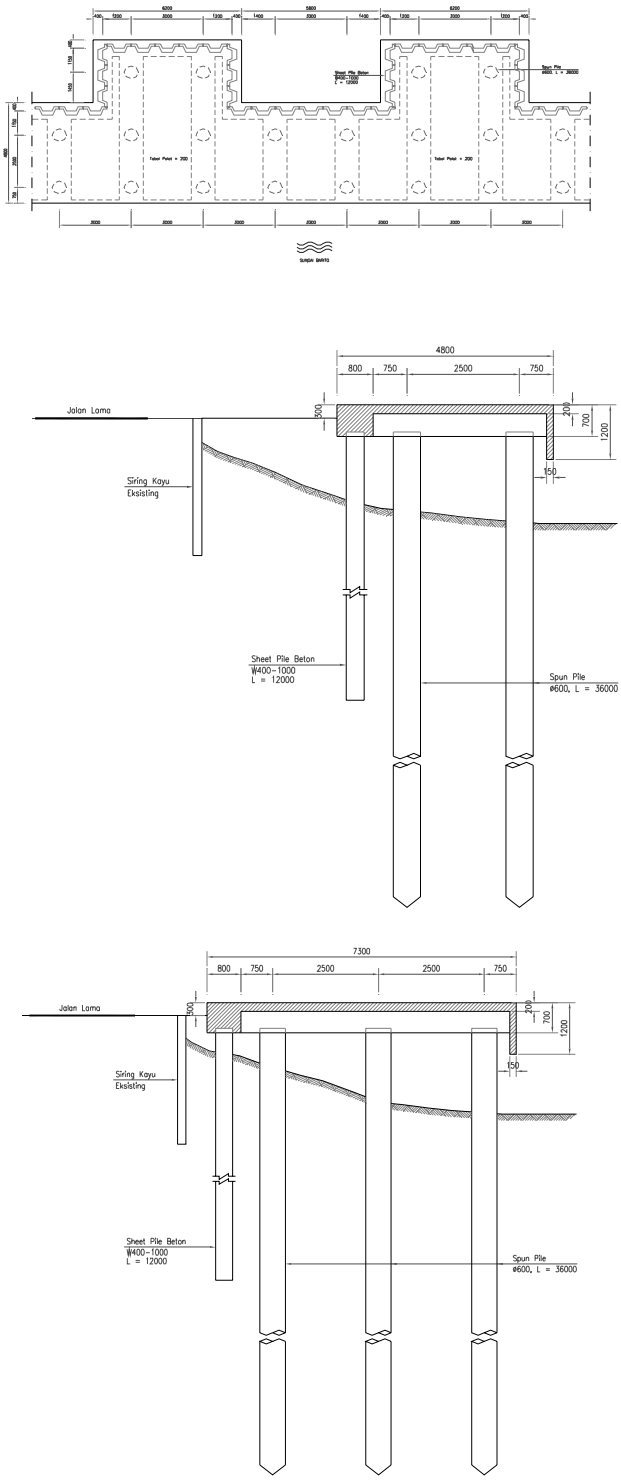


Figure 6. Site Plan of Construction System of Deck on Pile at Region A

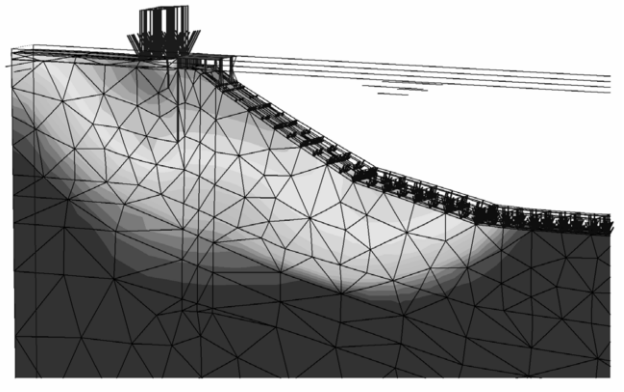


Figure 7. Result of slope stability analysis after construction of new structure (SF > 1.25).

4. CONCLUSION

The retaining wall with backfill system is impossible solution for very soft soil to soft soil condition

Analysis result shows that deck on pile solution more with have many advantages such as:

- Vertical load caused by dead load and life load will be transferred to the hard soil pass through pile foundation
- Back fill volume is not too big
- It is easy for construction and not expensive

REFERENCES

1. BMS 1992
2. Ensoft, LPILE
3. Marabahan Report, 2005
4. PLAXIS Ver. 7.2
5. PLAXIS 3-D, Tunnel Ver. 2.1
6. Robertson, P.K dan Campanella, R.G 1983. Interpretation of Cone Penetration Test, Canadian Geotechnical Journal.
7. Sanglerat G (1972), The Penetrometer and Soil Exploration. Interpretation of Penetration diagrams, Theory and Practice
8. SNI03-1726-2002