Thai Geoscience Journal 1(1), 2020, p. 57-62

ISSN 2730-2695 ; DOI : 10.14456/tgj.2020.5

Reinforced embankment constructed along irrigation canal

Kritsada Teerachavalvong, Surasak Kaipinit,
Taweephong Suksawat* and Kawin Saiprasertkij
Department of Rural Roads, Ministry of Transport, Thailand.
**Corresponding author: Taweephong2727@gmail.com*
Received 16 December 2019 ; Accepted 2 July 2020

Abstract
The Department of Rural Roads has reconstructed the asphalt concrete road during April to May 2016, KS.4064 that is along the Right Main Canal (RMC) of the Lam Pao Dam in Yang Talat district, Kalasin province, the northeast region of Thailand. The distance of road is 1.60km, approximately. During construction, the road embankment collapsed about 300 meters after the asphaltic concrete was paved. This paper focuses on the stability of reinforced road embankment on the KS.4064 by using geogrids and soil replacement methods in order to reinforce the embankment. The PLAXIS 2D software is used to analyze the Factor of Safety of the reinforced road embankment. The required minimum Factor of Safety of 1.30 for the rapid drawdown condition is considered as the criteria for this project. The results from simulations demonstrated 1.563 and 1.640 for geogrid reinforcement and soil replacement methods which indicates that the stability of slope is adequate even though the worst-case condition is considered.

Key words: Geogrid, PLAXIS 2D, Reinforced Embankment, Rural Roads, Soft Soil , Soil Replacement

Introduction

Infrastructure systems are the basic physical and organizational structures needed for the services and facilities necessary for an economy to function. Generally, it refers to the technical structures that support a society, for instance, highway, bridge, dam, tunnel, water supply, etc. (Suksawat, 2014).

Rural roads were numerous developed in rural areas of Thailand for the last fifteen years for the facility to societies, supplied as the connection linkage between cities from urban to sub-urban areas (Department of Rural Road, 2016). Therefore, the rural roads were dramatically expanded and enlarged until a present caused automobile gained popularity; consequently (Suksawat, 2008), numerous roads were constructed along the irrigation canals. However, the rural road in Kalasin province, KS.4064 locates on the northeast region of Thailand that failed during construction. This area called the Khorat plateau, which is composed of sand and silty sand-sized soil and covered with hilly landscapes presented higher soil strength than the central region.

The Department of rural roads has operated to reconstruct the asphalt concrete road, KS.4064 that is along the Right Main Canal (RMC) of the Lam Pao Dam in Yang Talat district, Kalasin. The KS.4064 constructed during April to May 2016 which is summer season in Thailand. It was constructed in 2016 and planned to continue until 22.00 km. The road collapsed one day after the asphaltic concrete was paved as shown in Figure 2. The 2-D Finite Element software, Plaxis 2D, was conducted to determinate the cause of failure. In general, the Plaxis 2D can used to perform deformation, stability and flow analysis for various types of geotechnical application by modelled either by a plane strain or an axisymmetric model. In this study, the Plaxis 2D was performed to determinate the Factor of Safety, FS, in order to evaluate the stability of road.

Figure 1: Asphalt concrete surface construction

Figure 2: The road collapsed one day after the construction

Approach/Methodology

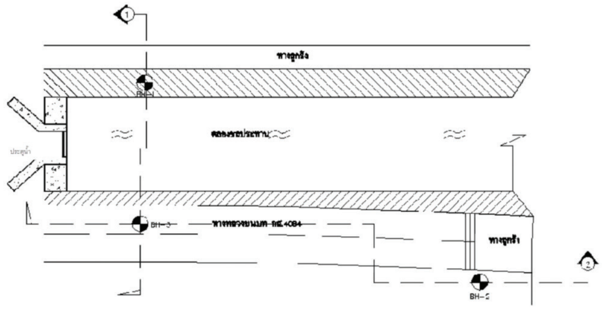
The Bureau of Test, Research and Development sent a team to look into the site. The type of damage was observed and the causes identified. The team would study two possible causes: a drop in the underground water level after the negative impacts of agricultural drainage water into irrigation areas, or natural conditions such as soil quality.

Both site and laboratory geotechnical testing were carried out to analyze the causes of the failure. Disturbed and undisturbed soil sample were taken from the selected site

Site Investigation

Three boreholes were conducted soon after failure occurred as shown in Figure 3. The BH-1 and BH-3 are tested on the opposite side of the first failure spot while BH-2 is tested on the stable slope out of the construction area (Sta 21+100). In addition, a test pit of 4.0 m depth was performed nearby BH-3 in order to collect undisturbed samples for direct shear and pinhole tests.

Section 1-1 and Section 2-2 (BH-1 to BH-3 and BH-3 to BH-2, respectively) show the soil profiles as illustrated in Figure 4. The first layer is soil-cement base and fill material having a thickness of 0.5 m to 1.0 m and underlain by loose to medium dense silty sand which extends down to about 3.0 m depth approximately. The shear strength parameters obtained from the direct shear test are cohesion vary from 7.0 to 12.0 kPa and internal friction angle around 25° to 28°. The very stiff to hard clay layer was found to underlie the loose to medium dense silty sand at 3.0 m onward having Standard Penetration test (SPT) more than 30 blows/foot.



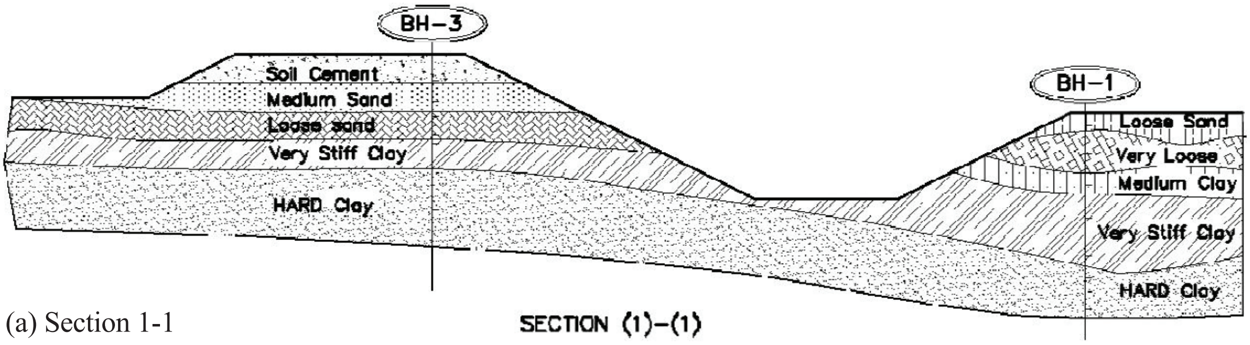
(a) Location of boreholes

(b) BH-1 and BH-3

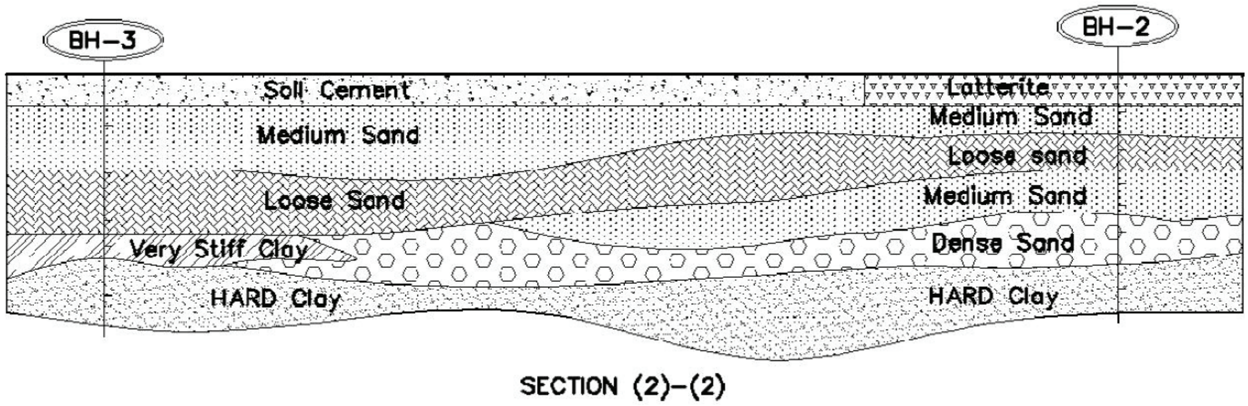
(c) Sampling with standard penetration test (SPT)

(d) Test pit sampling

Figure 3: Locations of soil boring and test pit



(a) Section 1-1



(b) Section 2-2

Fig. 4 Soil profile of Se ction 1-1 and Section 2-2

Figure 5 demonstrates the SPT with depth of the three boreholes. The SPT with Depth indicated the weak zone locates from 1.0 to 3.0 m then the SPT gradually increases with depth. After 6 meters depth, the SPT is greater than 30 Blow/foot. It implies that the failure surface should not be lower than 3.0 to 4.0 m from the surface. Finally, the BH-1 (located on the opposite site of the failure spot) is used as the representative Geotechnical parameters because it is the lowest SPT values. In addition, the pinhole testing results indicate ND1 class which indicates that Non- dispersive soil.

Finite Element Discretization

Finite element simulations are performed using the PLAXIS 2D software developed by Brinkgreve and Broere (2006) that allows for a realistic simulation of construction sequences. The basic soil elements are represented by the 2D, 15-node elements. The Mohr Coulomb Model (MCM) is selected to model the behavior of all soils.

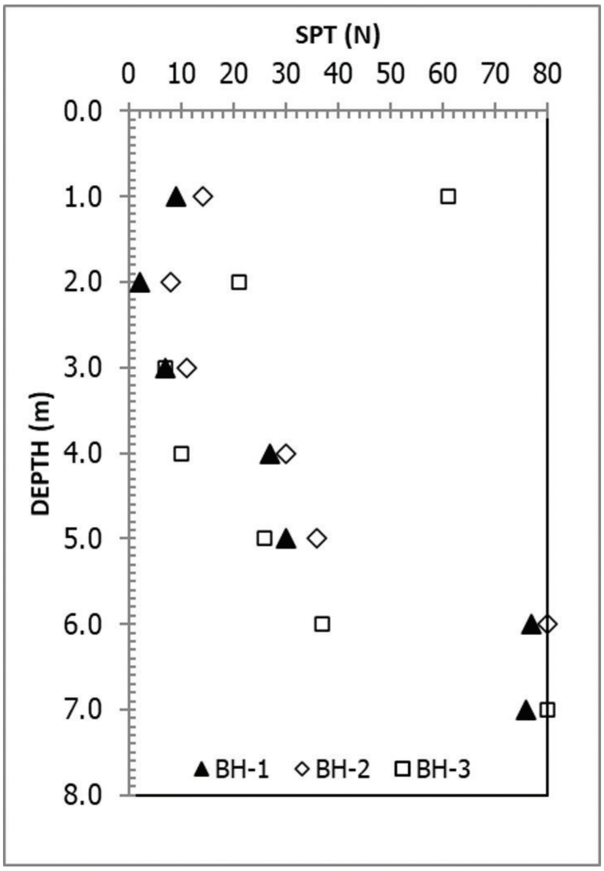


Figure 5: SPT with Depth

The strength reduction method is applied to evaluate the Factor of Safety (Farshidfar and Nayeri, 2015). Generally, the determination of the Factor of Safety for slopes is defined as the proportion of soil shear strength to the minimum shear stress required for creating preliminary failure following:

$$\text{Factor of Safety} = \frac{\text{Allowable strength}}{\text{Strength at Failure}} \quad (1)$$

In the Factor of Safety approach, the shear strength parameters like cohesion (c) and internal friction angle (ϕ) as well as tensile strength are successively until failure of the structure occurs.

Several solutions are proposed, for example, bearing unit, gabion wall, geosynthetic reinforcement, concrete pile wall and so on (Gu, 2011). However, two solutions are adopted which are geogrid reinforcement and soil replacement methods for 100 m and 300 m, respectively because budget is limited. The excavation depth of 3.0 m and 2.0 m for geogrid reinforcement method and soil replacement method, respectively, are requested to remove the existing soil and replace with the suitable materials. The advantages of Geogrid reinforcement method are lower excavation depth, faster construction time and less effect to agriculturists since it is not necessary to reduce the water level in the canals. However, Geogrid reinforcement is very expensive and it is not widely used in rural areas. On the other hand, the soil replacement method requires a greater volume of fill material as well as longer construction time but cheaper and easier for quality control during construction. The pros and cons of both methods are tabulated as shown in Table 1. The selected material type A (following DRR.204-2002) is applied as the filled material for the soil replacement method while the sub-base material (following DRR.202-2014) is used as the embankment material for the geogrid reinforcement method.

Table 1 comparison between pros and cons of soil replacement and geogrid

Method	Pros	Cons
Soil replacement method	- Cheap - Easy to control the quality of construction - Use filled material nearby construction site	- 3 m or more excavation is needed - May faced the flooding problem - Slow construction
Geogrid Reinforcement	- Faster than Soil replacement method - 2m excavation only - less effect to agriculturists since it is not necessary to reduce the water level	- Expensive - Required expert to control during construction - Not widely used in rural areas

Results

The appropriate material parameters obtained from back analysis as well as laboratory testing are tabulated in Table 2. The Factor of Safety is 1.036 which is compatible to the fail slope at Sta 21+500 for instability slope as shown in Figure 6.

Table 2 Soil Parameters from back analysis

Soil	γ_{unsat}	γ_{sat}	E (kPa)	c (kPa)	ϕ (°)
Embankment	18.0	20.0	10000	20	0
Layer_1	19.8	22.3	9000	1.5	25
Layer_2	19.9	22.2	9000	1.5	25
Layer_3	18.7	21.2	15000	15	35
Layer_4	18.7	21.7	67500	135	0
Layer_5	18.0	20.0	750000	150	0

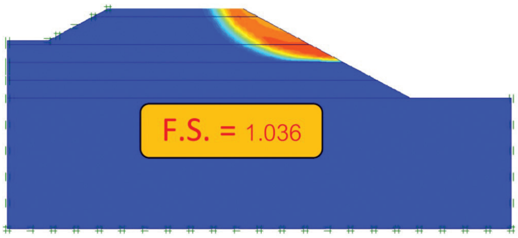


Figure 6: The slip surface of the back analysis model of Sta 21+500.

The minimum requirement of the Factor of Safety of 1.30 for the rapid drawdown condition is considered as the criteria for this project. Fill material of geogrid reinforcement and soil replacement methods is tabulated in Table 3 and geogrid properties for simulation is shown in Table 4, respectively.

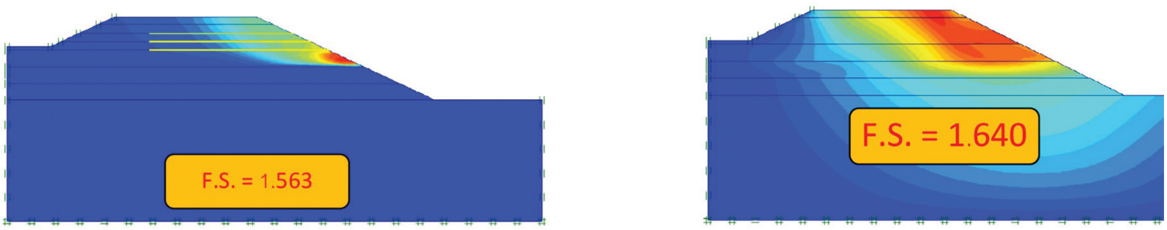
Table 3 Parameters for fill material

Soil	γ_{unsat}	γ_{sat}	E (kPa)	c (kPa)	ϕ (°)
Embankment	18.0	20.0	10000	20	0

Table 4 Parameters for geogrid material

Geogrid	TYEP	EA (kN/m)
HDPE Geogrid	ELASTIC	2000

The results from simulations demonstrated 1.563 and 1.640 for geogrid reinforcement and soil replacement methods, respectively as shown in Figure 7. Even though, the first method illustrated lower Factor of Safety, however, the displacement is lesser since higher stiffness than the soil replacement method.



(a) Geogrid reinforcement method (b) Soil replacement method

Figure 7: The Factor of Safety results

Conclusions

Rural road No.KS.4064 was constructed along the irrigation canal of Lam Pao Dam, Kalasin province during the dry season of 2016 and collapsed soon after paving phase. The cause of failure was investigated by the Bureau of Test, Research and Development together with the local officers a few days after.

Based on the remaining evidences as well as Geotechnical properties obtained from the several laboratory testings, the reasons are weak soil strength underneath together with rapid drawdown during construction. Furthermore, the failure occurrence not only on a roadside, but also on the existing ground opposite site as well. Therefore, the major reason of this road failure is the loose silty sand below the road construction.

In order to remedy this problem, two solutions are proposed, which are geogrid reinforcement method and soil replacement method. The advantages of the first method are faster construction, lower excavation and lesser effect to the farmer. However, the second method seems to be easier for construction and cheaper but cannot construct during rainy season because the high-water level. The Factor of Safety of both methods are greater than 1.3 which indicates that the stability of slope is adequate even though the worst-case condition is considered.

Acknowledgement

This research was supported by the Bureau of Rural Roads 16 (Kalasin), the Kalasin rural road district office, the Geotechnical Engineering research and development as well as our colleagues from the bureau of test research and development who provided insight and expertise that greatly assisted this research.

References

Brinkgreve, R.B., & Vermeer, P. A. (2006). *PLAXIS 2D Manual.* Rotterdam: Brookfield.

Department of Rural Road. (2016). Standard for rural road construction. Bangkok: Bureau of Test, Research and Development, Department of Rural Road.

Farshidfar, N., & Nayeri, A. (2015). Slope Stability Analysis by Shear Strength Reduction Method. *Journal of Civil Engineering and Urbanism, 5* (1), 35-37.

Gu, J. (2011). *Computational modeling of geogrid reinforced soil foundation and geogrid rein forced base in flexible pavement.* (Doctoral dissertation). Louisiana: Louisiana State University and Agricultural and Mechanical College.

Suksawat, T.Z. (2008). *Numerical simulation of SDCM and DCM piles under axial and lateral loads and under embankment load: A parametric study No. GE-08-09* (M. Eng. Thesis). Bangkok: Asian Institute of Technology.

Suksawat, T. Z. (2014). *Geotechnical infrastructure asset management focusing on performance deterioration process of ground anchors* (Doctoral dissertation). Kyoto: Kyoto University.