REMEDIAL STRUCTURES TO STABILIZE LONG XUYEN RIVERBANK TO PREVENT SLIDING IN AN GIANG PROVINCE,VIETNAM

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Abstract

Sliding of structures along riverbanks in An Giang province has caused serious losses for local people and the current stabilized methods have been ineffective to treat sliding issues sustainably. This study attempts to propose some remedial methods to prevent sliding of structures along the Long Xuyen riverbank in An Giang. These structures were designed, constructed at the selected sites, and monitored their field performance for a flood cycle which is a year. The two stabilized structures were proposed, analyzed, and successfully constructed at the two selected sites. The field monitoring instruments such inclinometer casing and groundwater observation wells also were fully installed to obtain the field data to evaluate field performance of the proposed structures.

Keywords: Inclinometer, Sheetpile, Sliding, Slope monitoring, Slope reinforcement, Slope stability, Slope stabilization, Soft ground

Introduction

Several sliding of structures along riverbanks in An Giang province which locates in the Southwest of and about 200 km from Ho Chi Minh City (Figure 1) have occurred recently such as Sliding at km 88 + 937 on the National Highway No. 91 on March 22nd, 2010 (Tran-Nguyen et. al. 2011, Tran-Nguyen & Le 2011) (Figure 2). Many houses, manufacturers, and highway embankments along riverbanks have failed due to riverbanks' sliding like a sliding of the Hau riverbank on May 26th, 2012 (Figure 3). This failure occurred about 100 m long and 20-25 m wide to damage about 25 houses. These failures have caused serious losses for An Giang people and the local people have searched for effective solutions to treat the sliding problems.

An Giang province locating at the Vietnam-Cambodia border has a network of rivers formed from the Mekong River when it reaches the Vietnam land. The Mekong River is divided into the two big rivers: Hau River and Tien River (Figure 1). The network of rivers brings both advantages and disadvantages to An Giang province such as water transportation and sliding.

Some typical stabilized structures have applied to remedy the sliding of riverbanks in An Giang but it seems that these solutions have not been sufficient enough to mitigate the sliding issues. Therefore, more stabilized solutions need to be studied, tested, and applied to prevent the sliding of riverbanks sustainably in An Giang province.

This paper attempts to propose some stabilized structures to reinforce the Long Xuyen which is a branch of the Hau River in An Giang. These structures will be analyzed, constructed, and monitored for a flood cycle which is a year. If the proposed structures work properly in the field, these structures can be adopted to others locations that have similar conditions in An Giang province and also to other provinces in the Mekong Delta.

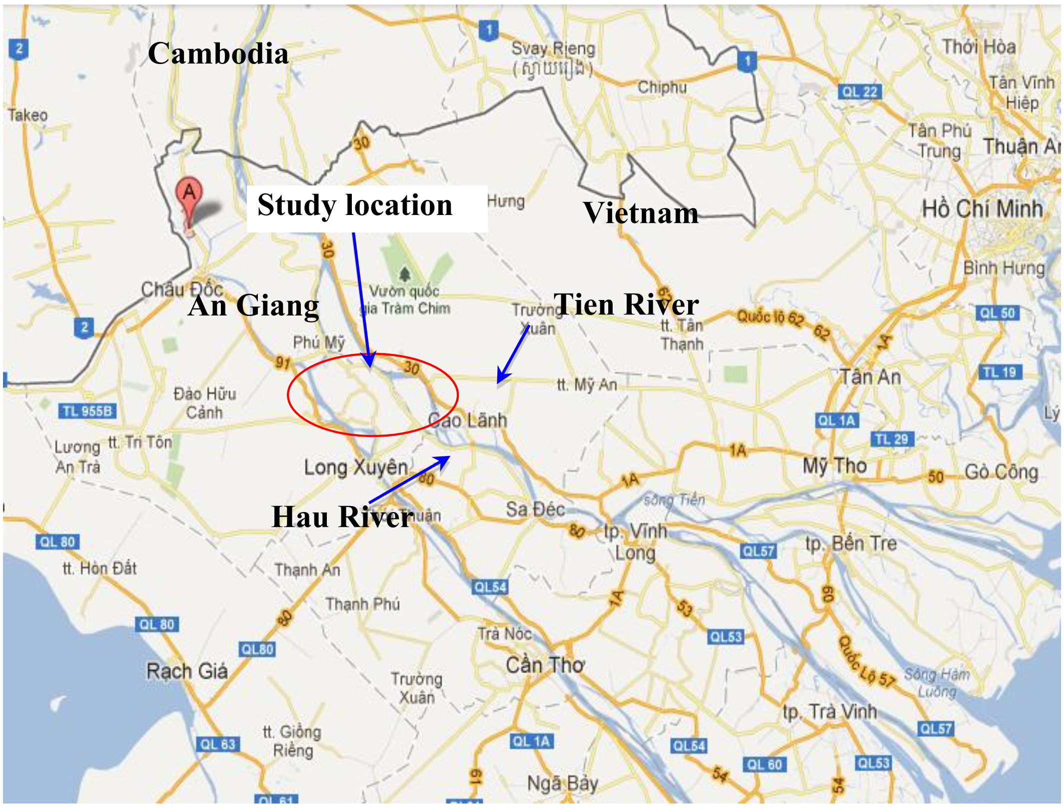


Figure 1. Location of An Giang province, Vietnam (Google maps)

Figure 2. A sliding at km 88 + 937 on the national highway No. 91 along the Hau riverbank in Binh My, An Giang on March 22nd, 2010

Figure 3. A sliding of the Hau riverbank in Long Xuyen, An Giang on May 26th, 2012 (An Giang newspaper)

Site Conditions

Two locations about 150 m apart along the Long Xuyen riverbank were selected for this study. The Long Xuyen River is a branch of the Hau River and in the Long Long Xuyen City of An Giang province (Figure 4). Two boreholes were drilled for soil investigation at the two locations. Two trial structures were designed and constructed at these locations.

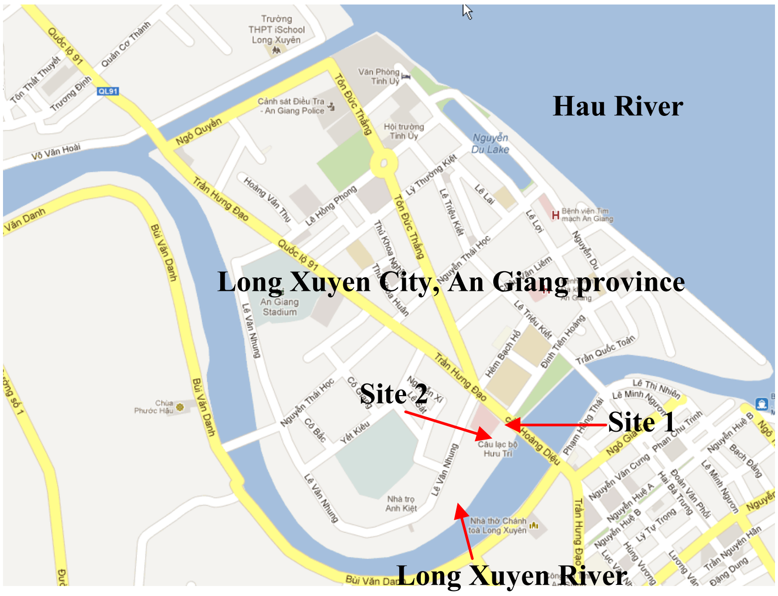


Figure 4. Locations of the two selected sites in Long Xuyen City, An Giang province, Vietnam (Google maps)

In general, geometry of the two sites is similar and flat. The average ground surface elevation is about +2.80 m, and the ground surface is partially underwater in the flood season which is from August to December every year.

The water level in the Long Xuyen River is directly dictated by the water flow regime of the Hau River (Figure 4). The Long Xuyen River has two daily cycles of high and low tides.

The highest and lowest water levels in the river are +2.90 m and -1.00 m (at a frequency of 1%) in the flood and dry seasons, respectively. There are the two seasons per year in An Giang: rain or flood (May to October) and dry seasons (November to April).

Site No. 1

The stabilized structure at the first site was built to prevent sliding of the riverbank to protect houses built along the Long Xuyen River. A borehole drilled to investigate geological properties locates at the riverbank and was close to the stabilized structure. In general, three soil layers found along a 45-m soil profile. A thin stiff clay or filled layer is about 1.7-2.0 m at the top soil surface. A 27-30-m very soft clay layer (*SPT* = 0-3) is underneath the top layer. A fine medium dense sand layer is at the bottom of the borehole. The soil properties of the soil layers are given in Table 1.

Table 1. Soil Properties of The Site No. 1

Layer	Unit Weight	Void Ratio	Liquid Limit	Plasticity Index	Direct Shear Test	
	γ_w kN/m^3	e_o	*LL* %	*Ip* %	*c* kN/m^2	ϕ Deg.
Soft clay (CL)	14.7	2.27	68.9	33.7	5.4	$6^0$12’
Fine sand (SP)	20.2	0.55	-	-	8.4	$27^0$20’

Site No. 2

The second stabilized structure was constructed against sliding of an embankment along the Long Xuyen riverbank. A failure has taken place under construction at this location (Figure 5). This location has three soil layers along a 30-m soil profile. A 20-22-m very soft clay layer lies between a 1.5-m top stiff clay layer and medium stiff clay underneath. The properties of soil layers along the soil profile are printed in Table 2.

Table 2. Soil Properties of The Site No. 2

Layer	Thickness	Unit Weight	Void Ratio	Plasticity Index	Direct Shear Test	
	(m)	γ_w kN/m^3	e_o	*Ip* %	*c* kN/m^2	ϕ Deg.
Medium Stiff Clay	1.5	19.8	0.80	19.2	19.4	$13^0$44'
Soft Clay	22	15.4	2.01	22.2	14.2	$5^0$28'
Medium Stiff Clay	> 30	19.4	0.72	16.8	20.9	$14^0$57'

Figure 5. A sliding of the Long Xuyen riverbank under construction of a stabilized structure in an Giang on May 15th, 2012

Geohydrological Properties

The water levels of the Long Xuyen river also are affected by the two key seasons of a year: rain season and dry season. The rain season from May to October causes full saturation for the soil mass in the riverbank, whereas the dry season from November to April causes the water levels of the river and groundwater reaching the lowest level. Thus, the dry season raises high potential sliding of riverbanks. A system of three groundwater observation wells was installed at a location between the two sites for groundwater monitoring.

Methodology

The proposed stabilized structures need to meet the following requirements:

- Stabilize sustainably the riverbank against sliding.
- Utilize local materials.
- Construct easily using domestic technologies.
- Cost reasonably for construction.

Therefore, this study employs conventional methods to design and analyze these structures.

Slope Stability Analysis

The Bishop method which is based on the Limit Equilibrium Theory was used to analyze stability of riverbanks based on Factor of Safety, *F.S.* The Bishop method assuming a failure surface to be circular and *F.S.* is defined by a ratio of resisting moment to driving moment (1).

$$F.S. = \frac{Resisting\ moment}{Driving\ moment} \qquad (1)$$

A factor of safety is determined using method of slices taking inter-forces of slices into account (Duncan & Wright 2005) or simplified Bishop method and showed in Equation (2) and Figure 6.

$$F.S. = \frac{\sum \lfloor c'.\Delta l.\cos\alpha + (W - u.\Delta l.\cos\alpha).\tan\phi' \rfloor / m_\alpha}{\sum W.\sin\alpha} \quad (2)$$

where c' − effective cohesion, ϕ' − effective friction angle, Δl − length of each slice base along slip surface, W − total weight of each slice, α - angle of the base of each slice to the horizontal direction, u − pore water pressure, $m_\alpha = \cos\alpha + (\sin\alpha.\tan\phi')/(initial\ F.S.)$.

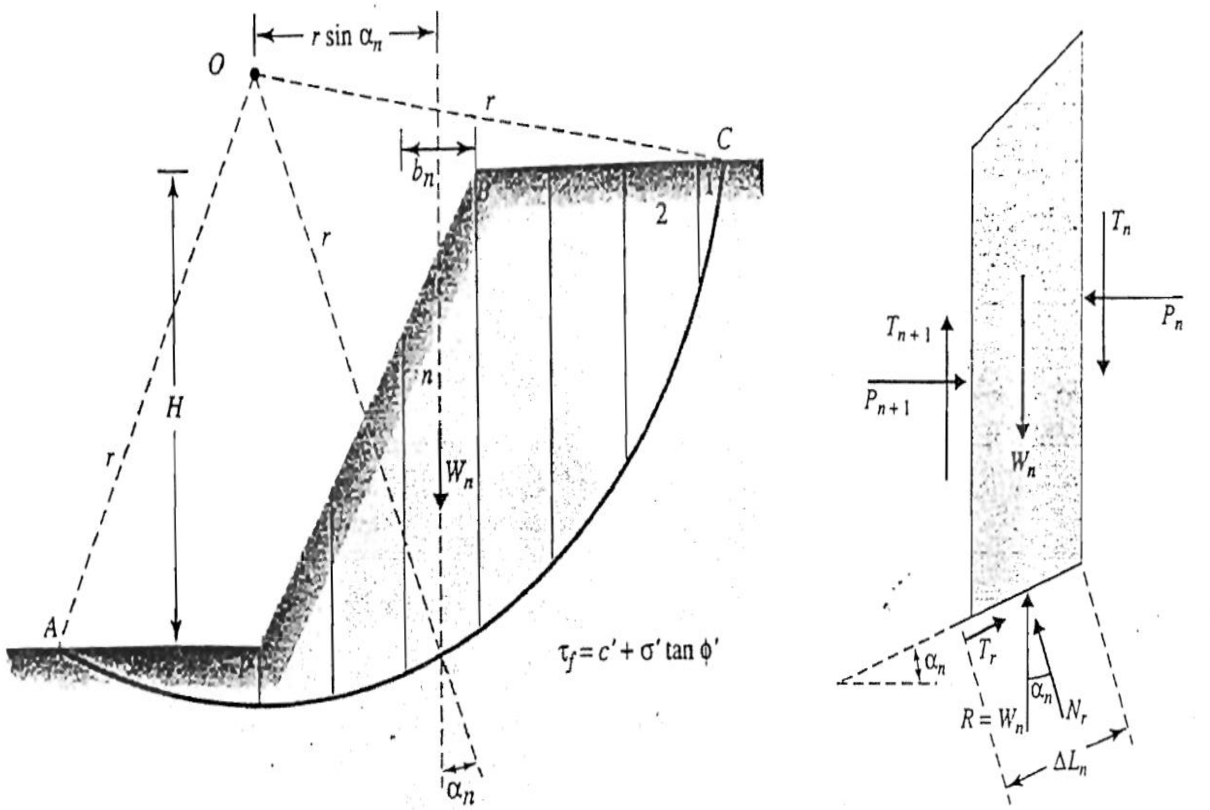


Figure 6. Factor of safety determined using the method of slices taking inter-forces of slices into account (Das 2006)

Monitoring

The proposed structures are monitoring for a flood cycle which is a year after the structures are constructed. The monitoring is to obtain field data such as deep lateral movement of the soil mass along the riverbank, surface movement, and groundwater and surface water levels variation (Li 2003). Based on the soil investigation, only one system of groundwater observation wells is needed for the two sites and locates at the middle of the sites. An inclinometer casing was installed at each site to monitor deep lateral movement of the soil mass right behind the proposed structures. Lateral displacement data is periodically collected by an inclinometer probe. Surface movement data is weekly obtained using a topographic instrument to observe any unusual movement of the ground surface. Groundwater data is weekly measured using a water level indicator at high and low tides. Figure 7 shows a plan view of field instruments' arrangement at the two sites.

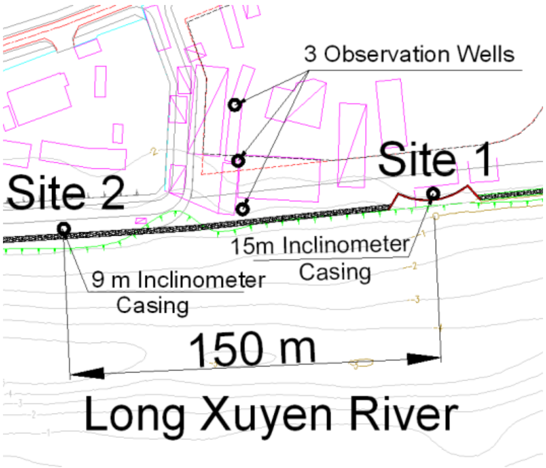


Figure 7. Plan view of field instruments' arrangement at the two sites

Design of the Proposed Structures

The proposed structures were designed to meet requirements in terms of economy and engineering and were based on results of previous studies (Tran-Nguyen et al. 2011, Tran-Nguyen & Le 2011, Le Xuan Viet & Tran Nguyen Hoang Hung 2011a,b,c, Le Xuan Viet 2011). One of key issues in An Giang province that there is lack of diversity of stabilization methods to mitigate sliding. This study attempts to provide more options to prevent sliding in An Giang and to validate feasibility and effectiveness of the proposed structures, and encourage the local people to apply these structures to province wide confidently. Figure 8 shows a plan view of the two selected sites along the Long Xuyen riverbank. The site No. 1 applied precast concrete sheetpile wall combined with sand compaction piles to stabilize the riverbank. The site No. 2 utilized grouted stone wall combined with timber piles, concrete piles, and sand compaction piles to protect a road embankment along the riverbank.

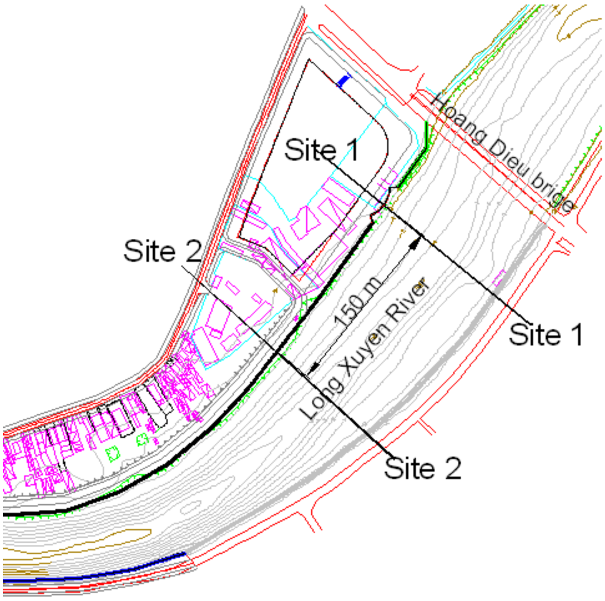


Figure 8. A plan view of the two selected sites for this study in Long Xuyen City, An Giang province, Vietnam

The Proposed Structure No. 1 - Precast Concrete Sheetpile Wall Combined with Sand Compaction Piles

The precast sheetpile wall plays a role to prevent deep sliding of the soil mass along the riverbank. Figure 9 presents a cross-section of the structure. The sand compaction piles improve and reinforce soft clay layer behind the wall, and enhances capacity against deep siding of the structure. Each concrete sheetpile which has 12 m long, 1 m wide, and 0.4 m thick connects together by notches along its longitudinal edge. A 15-m concrete anchor was installed at the middle top of the sheetpile wall to minimize lateral displacement at the top of the wall.

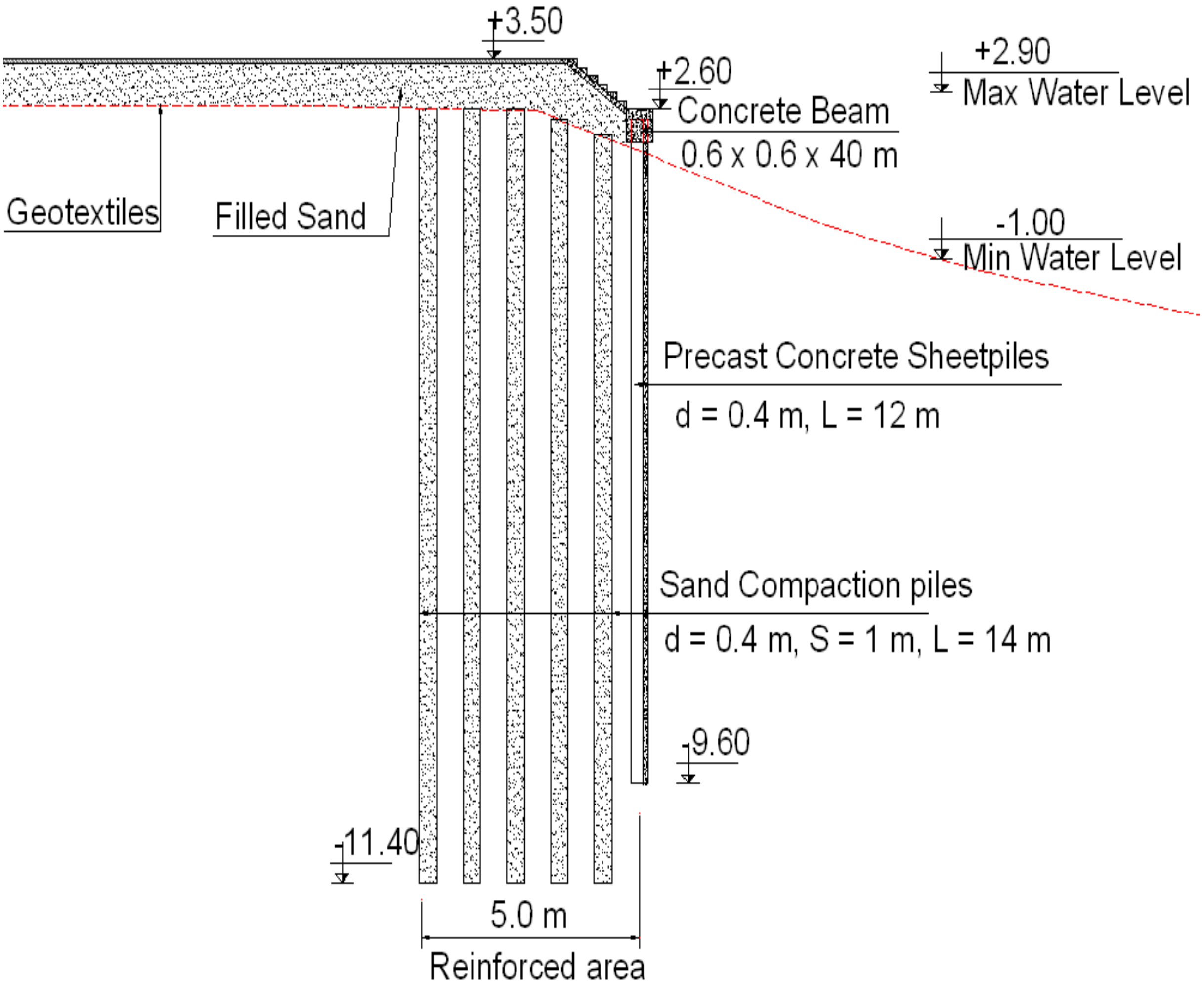


Figure 9. A cross-section of the proposed structure for the site No. 1

The Proposed Structure No. 2 – Grouted Stone Wall Combined with Timber Piles, Concrete Piles, and Sand Compaction Piles

A grouted stone wall retains fill clay of the road embankment along the riverbank and protects the slope against erosion. The sand compaction piles installed with 9 m long and 20 m wide reinforce and improve the soft clay layer to carry embankment load and to prevent deep sliding. The timber piles and precast concrete piles support foundation of the grouted stone wall. Gabions stabilize the riverbed in the front of the structure to prevent erosion and to create counter forces to enhance the stability of the whole structure. Figure 10 displays a typical cross-section of the proposed structure for the site No. 2.

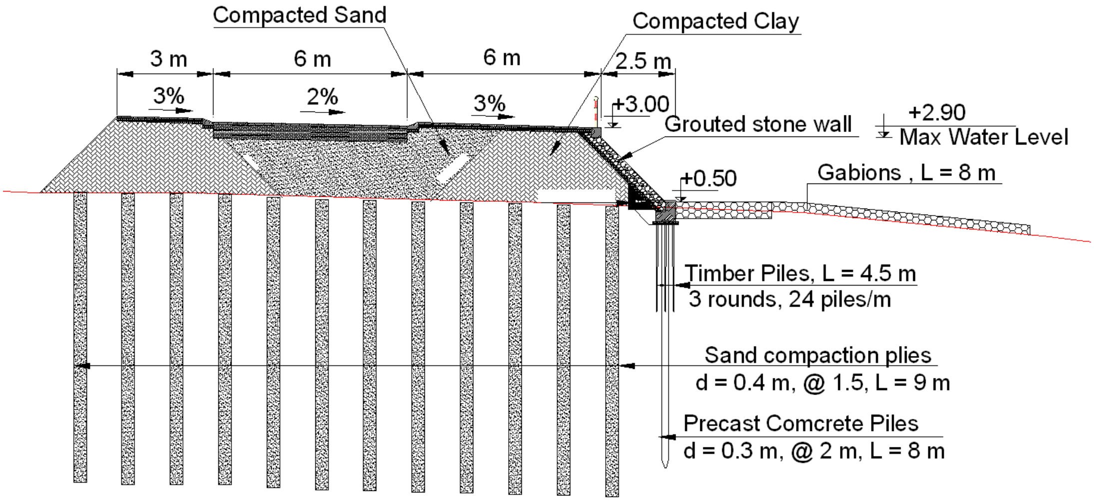


Figure 10. A cross-section of the proposed structure for the site No. 2

Analysis Results

According Vietnam Code for Slope Stability (22 TCN 262-2000), a FS obtained using the Bishop method should not be less than 1.4 to guarantee a structure against sliding safely. The Slope/W 2007 software was utilized for slope stability analysis. Two major cases - the highest and lowest water levels in the river - were applied for FS analysis.

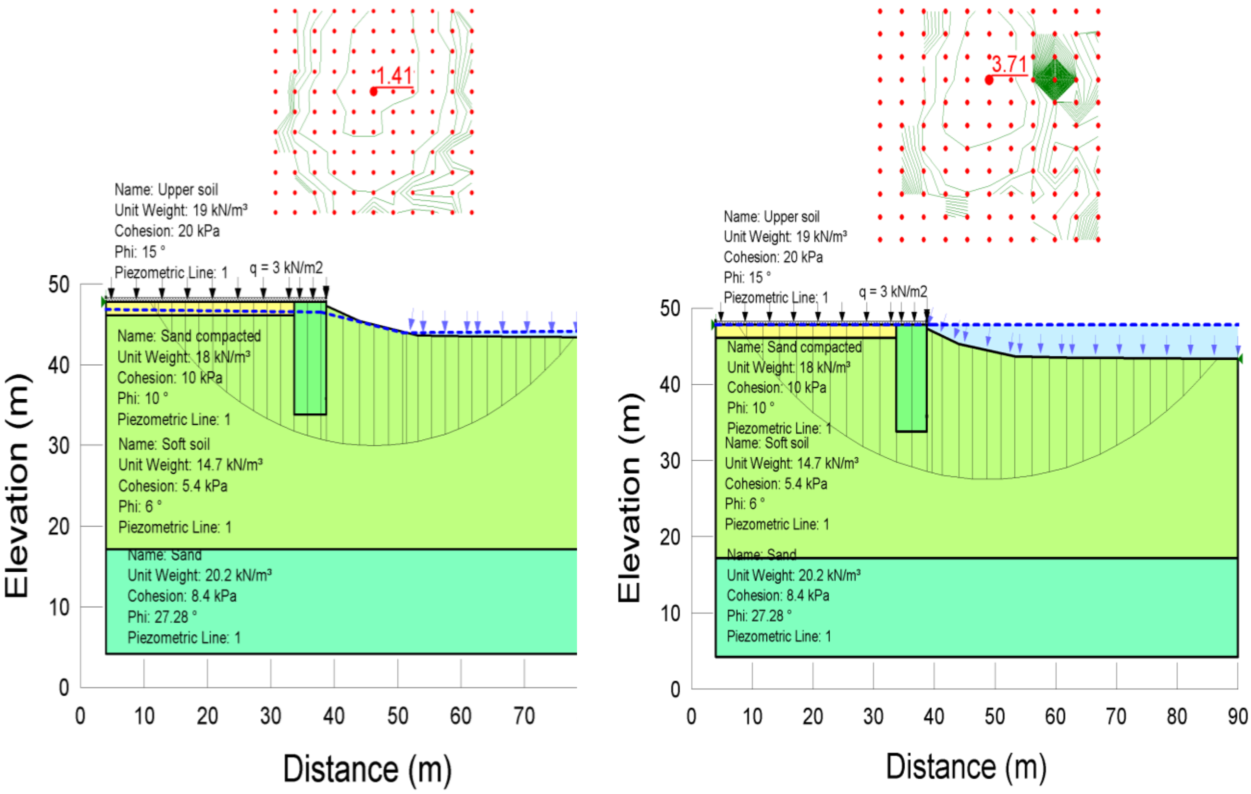
The Proposed Structure No. 1 - Precast Concrete Sheetpile Wall Combined with Sand Compaction Piles

The analysis results using the Slope/W 2007 software are given in Table 3 and Figure 11. It can be seen that the FS of the both cases meet the requirement of the 22 TCN 262-2000 which is larger than 1.4. At the lowest water level in the river, the groundwater level in the soil mass also reaches the lowest level. The shear strength in the soil mass reaches the highest value due to the lowest pore water pressure value in the soil mass. The counter force of the water in the river in the front of the structure is lowest. The counter force decreases faster than the shear strength increases. Therefore, FS becomes the lowest. The annual statistics on sliding of An Giang Department of Natural Resource & Environment shows that a large number of sliding took place in the dry season or the lowest water level in the river.

On the contrary, at the flood season, the water in the river reaches the highest level and is maintained for months. The flood season which is also the rain season in An Giang may saturate fully the soil mass. Consequently, the shear strength in the soil mass reaches the lowest value. However, the highest water level in the river provides a counter force against sliding toward the river. This counter force affects immediately to sliding, whereas the shear strength loses slowly. Thus, the *FS* remains high.

Table 3. The*F.S.* Analysis Results for The Site No.1 Using the Slope/W 2007 Software

	The Highest Water	**The Lowest Water**
F.S.	3.71	1.41



(a) (b)

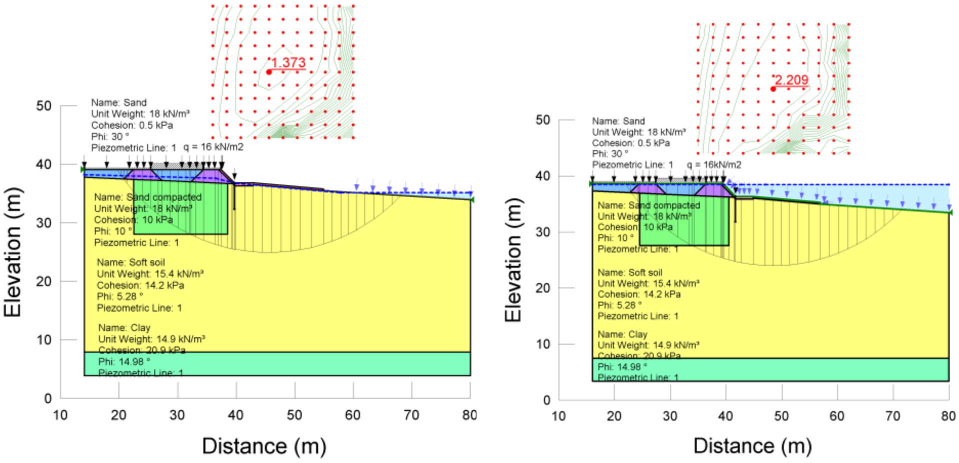
Figure 11. FS analysis for the proposed structure No. 1 using the Slope/W 2007 software for the highest and lowest water levels in the Long Xuyen river. (a) Slope stability analysis for the lowest water level in the river, (b) Slope stability analysis for the highest water level in the river

The Proposed Structure No. 2 - Grouted Stone Wall Combined with Timber Piles, Concrete Piles, and Sand Compaction Piles

Similarly, the stability of this proposed structure was also analyzed using the Slope/W 2007 software. The results display in Table 4 and Figure 12. In this case, the *FS* at the lowest water level in the river is less than 1.4. However, this FS is acceptable because the calculated lowest water level (-1.00 m) only appears a few days in the dry season with a frequency of 1%, while the daily lowest water level in the river is around ±0.00 m. Furthermore, An Giang authorities approved this proposed structure to reduce the total construction cost. In other words, this design qualified for the construction.

Table 4. The *FS* Analysis Results for The Site No. 2 Using the Slope/W 2007 Software

	The Highest Water	The Lowest Water
F.S.	2.21	1.37



(a) (b)

Figure 12. FS analysis for the proposed structure No. 2 using the Slope/W 2007 software for the highest and lowest water levels in the Long Xuyen river. (a) Slope stability analysis for the lowest water level in the river, (b) Slope stability analysis for the highest water level in the river

Field Monitoring

The monitoring is to obtain field data such as deep lateral movement of the soil mass along the riverbank, surface movement, and groundwater and surface water levels variation [7]. Based on the soil investigation, only one system of groundwater observation wells is needed for the two sites and locates at the middle of the sites. An inclinometer casing was installed at each site to monitor deep lateral movement of the soil mass right behind the proposed structures. Lateral displacement data is periodically collected by an inclinometer probe. Groundwater data is weekly measured using a water level indicator at high and low tides. Figure 5 shows a plan view of field instruments' arrangement at the two sites.

Groundwater fluctuation has been weekly and monthly measured and shown in Figure 13. Field lateral displacement measured using a Geokon inclinometer probe is plotted in Figure 14.

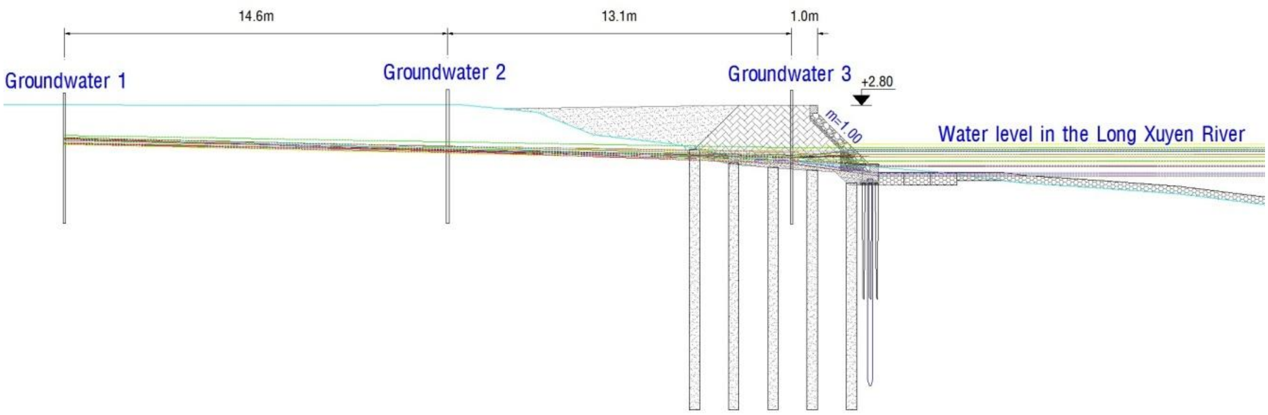
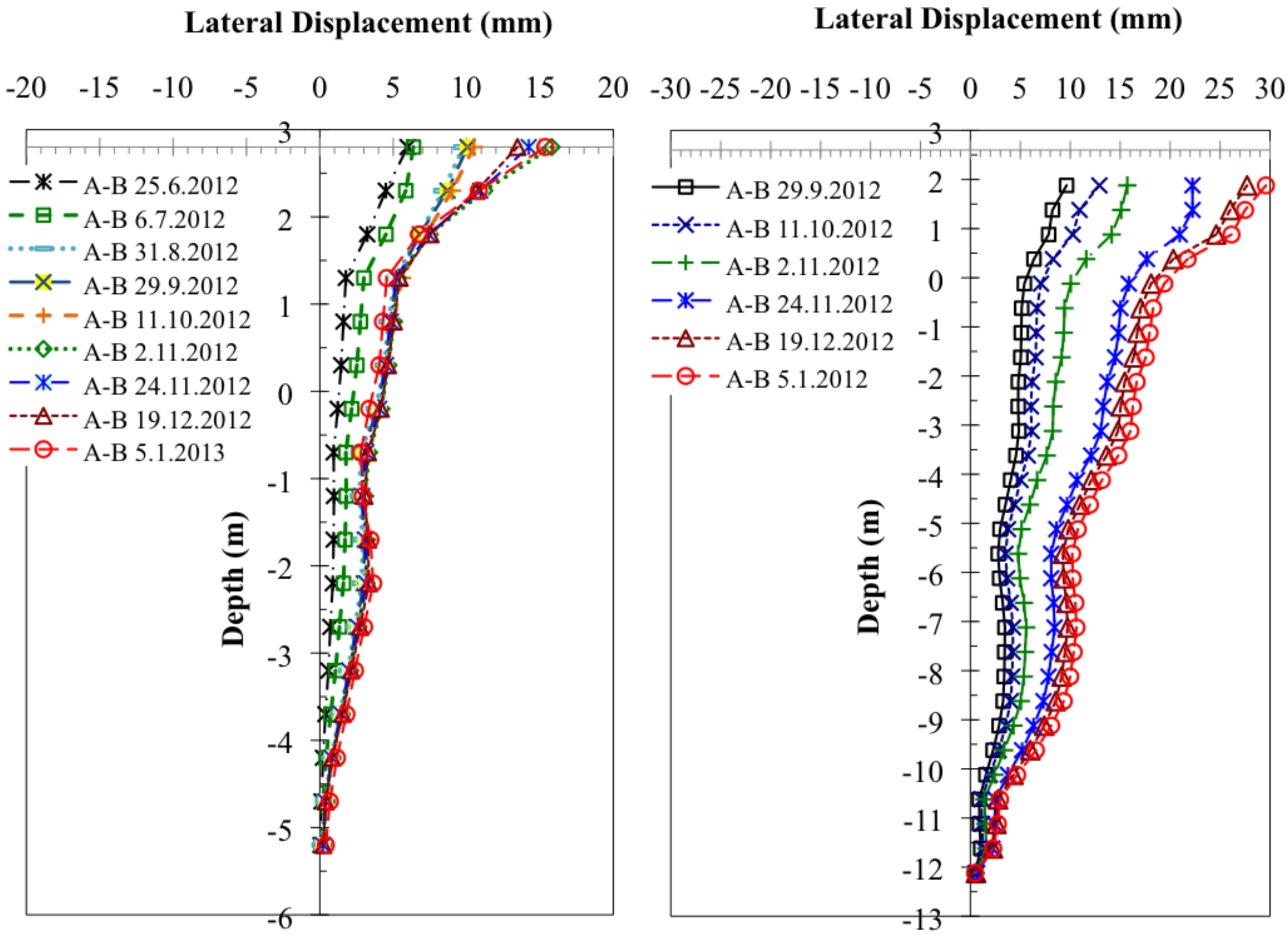


Figure 13. Groundwater variation obtained from the 3 wells installed between the two sites



(a) Site No. 1 (b) Site No. 2

Figure 14. Monitoring results of lateral displacement for the two sites for six months

To verify field performance of the proposed structures, stability analysis using the Slope/W 2007 software was carried out using the field monitored data. The results (Table 5) indicate that the proposed structures have worked well after six months.

Table 5. Factor of Safety Analysis for the Two Sites based on the Field Monitoring Data

	High Monitored Water Level	Low Monitored Water Level
Site No.1	2.75	2.12
Site No.2	1.73	1.47

The monitoring process is in progress until March 2013 to validate the effectiveness and feasibility of the proposed structures before submitting the official guidelines how to apply the proposed structures for other locations having similar conditions. The proposed structures need to be observed during the flood season, which is from August to December.

Conclusions

The two proposed stabilized structures to stabilize the Long Xuyen riverbank were successfully designed and constructed at the two selected sites. The structures are demonstration of a system of stabilization methods (from the JICA-SUPREM B2-02 project) that can be appropriately applied to mitigate sliding issues in An Giang. The monitoring instruments such as groundwater observation wells and inclinometer casings were also installed. The proposed structures have worked properly for six months after constructed. The monitoring process is in progress for the whole flood cycle, which is a year to validate effectiveness and feasibility of the proposed stabilized structures.

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References

[1] J.M Duncan, and S.G.Wright, *Soil Strength and Slope Stability*, John Wiley & Sons, New Jersey, United States, 2005.

[2] L.X. Viet, and T.N.H. Hung, "Sliding of highway embankments along riverbanks on the highway No. 91 in Binh My, An Giang," *Journal of Transport and Communications*, Vol. 6, pp. 17-20, 2011. (in Vietnamese)

[3] L.X. Viet, and T.N.H Hung, "Remedial solutions for the failure at the highway No. 91 in Binh My, An Giang," *Journal of Transport and Communications*, Vol. 7, pp. 15-18, 2011. (in Vietnamese)

[4] L.X. Viet, and T.N.H. Hung, "Sliding of embankments along riverbanks on soft ground in Nhon Hoi ward, An Phu district, An Giang," *Journal of Construction*, Vol. 8, pp. 68-71, 2011. (in Vietnamese)

[5] L.X. Viet. *Investigation on Sliding of Highway Embankment of the National Highway No. 91 at Binh My, An Giang*, Thesis (Master's), Ho Chi Minh City University of Technology, Vietnam, 2011. (in Vietnamese)

[6] A. Li, *Field Monitoring of a Saprolite Cut Slope*, Thesis (PhD), The University of Hong Kong, China, 2003.

[7] H.H. Tran-Nguyen, C.V.H. Nguyen, H.H. Tran, and X.V. Le, "Sliding of highway embankments along riverbanks on soft ground: A case study," In: *Proceedings of the 5th Symposium on Deformation Characteristics of Geomaterials,* Seoul, South Korea, Vol. 2, pp. 1282-1287, 2011.

[8] H.H. Tran-Nguyen, and V.X. Le, "Failures of highway embankments along the Hau riverbanks: Causes and remidial solutions," In: *Proceedings of the International Conference on Geotechnics for Sustainable Development*, Hanoi, Vietnam, pp. 909-916, 2011.

[9] Vietnam Ministry of Transport, *Code of Survey and Design Highway Embankments on Soft Ground*, Code No. 22 TCN 262-2000, 2000. (in Vietnamese)

[10] B.M. Das, *Principles of Geotechnical Engineering,* Nelson, Connecticut, United States, 2006.