Design and Construction Concrete Sheet Piles for Riverine Embankment Work in Mekong River Delta, Vietnam

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***Abstract* – Recently, in the Mekong Delta, Vietnam, river bank erosion has been very complex and serious, causing great economic and social losses. In particular, there are very serious river bank erosion with wide and very deep areas such as Vam Nao river-An Giang, Tien river passing Dong Thap… The solution of embankment is commonly used with prestressed reinforced concrete sheet piles, which is limited in pile length; or with a combination of steel pipe plywood which has high price. To overcome this disadvantage, the article proposes the solution of spun concrete pile wall in combination with prestreed reinforced concrete sheet piles with shorter length (referred to as semi-continuous pipe-sheet pile wall) for the riverine embankment wall in the Mekong Delta, typically the embankment of Vam Nao river. Based on the results of calculation and analysis, this concete pipe-sheet pile wall structure is a logical design solution in weak geological conditions and deep erosion.**

***Keywords* – Spun Concrete Pile, Prestressed Reinforced Concrete Sheet Pile, Concrete Pipe- Sheet Pile, Vam Nao River.**

I. BASIS AND PROCEDURE OF DESIGN

According to the depth of the pile wall, the upper part of the bottom altitude after erosion or the altitude on the shuttle (referred to as the upper part) is responsible for preventing landslide and shallow sliding [11]; The lower part of the bottom altitude or the altitude on the shuttle (referred to as the lower part) is responsible for preventing deep sliding and remaining stable for the wall structure. Thus, the solution of the two components has different design: the upper part has continuous pile wall structure, while the lower part has interrupted pile wall structure, named the semi-continuous pipe-sheet pile wall as shown in Figure 2 [3].

The lower part of the semi-continuous pipe-sheet pile wall is capable of preventing deep sliding (resurfacing) according to the arch effect principle, depending on the factors such as the internal friction angle of ground, undrainage resistance (S_u), elastic module (E_s), distance between sheet piles, etc. To solve this problem, the graphic solution and finite element method has been applied (ProSheet v.2-2, Geo5). The procedure of key steps for calculating the semi-continuous pipe-sheet pile wall design is as follows:

Step 1: Selection of structures and materials: Soft wall diagram with or without anchor and prestressed concrete pile and commonly selected steel sheet pile material.

Step 2: Preliminarily determine length (L_1, L_2, figure 1) and cross section size:

Determine length of spun concrete piles (), L_1: determined according to experience or graphic solution method through making force polygon and line polygon [5] (figure 1);

Determine size of the cross section of spun concrete piles according to length L_1(according to the manufacturer's shaping);

Determine length of prestressed reinforced concrete sheet piles (CV), L_2: Preliminarily select pile length CV, $L_2 = (0.6 \div 0.7)\ L_1$, using the finite element method to check and official determine L_2 (according to condition of strength and use

Step 3: Analyze the structure and calculate for approval of the structure. Use the finite element method to analyze the structure and approve according to condition of limitation on strength and use of the current procedures

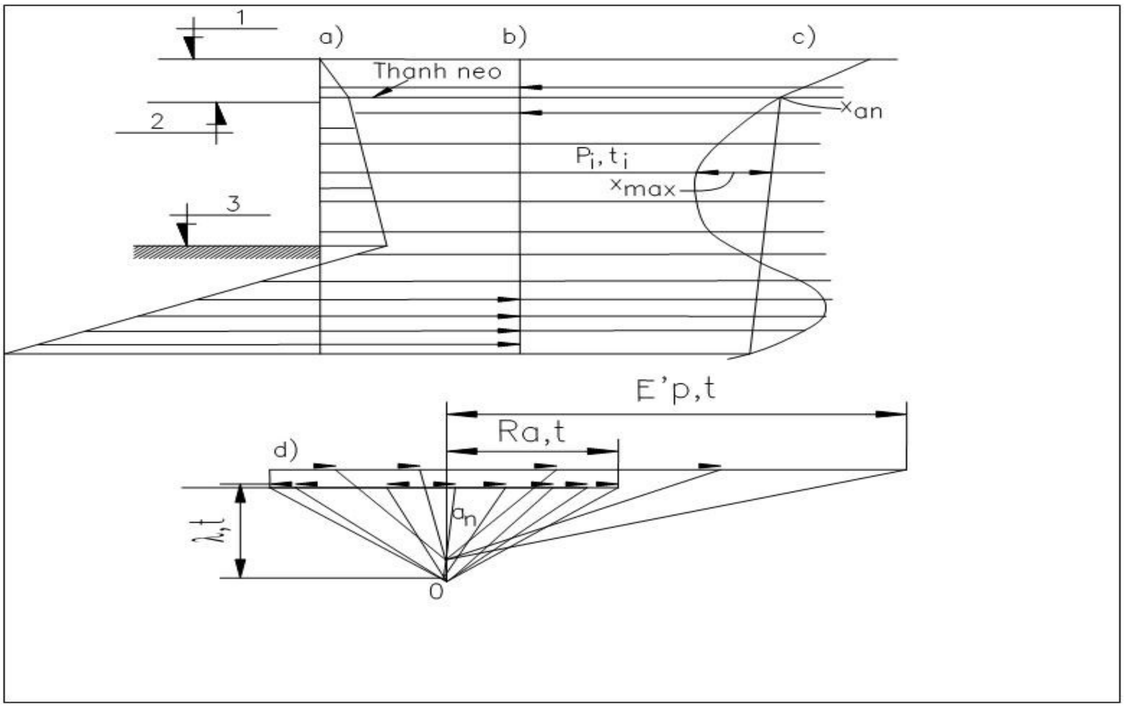


Fig. 1. Diagram to of graphic solution calculation of pile wall to preliminarily determine of length of pipe pile (L1), sheet pile (L2)[5] a- sum graph of active and passive pressure; b- diagram of calculation load; c-line polygon; d- force polygon; 1-Design altitude; 2- Water level of calculation; 3- Bottom altitude, upper altitude of the shutter.

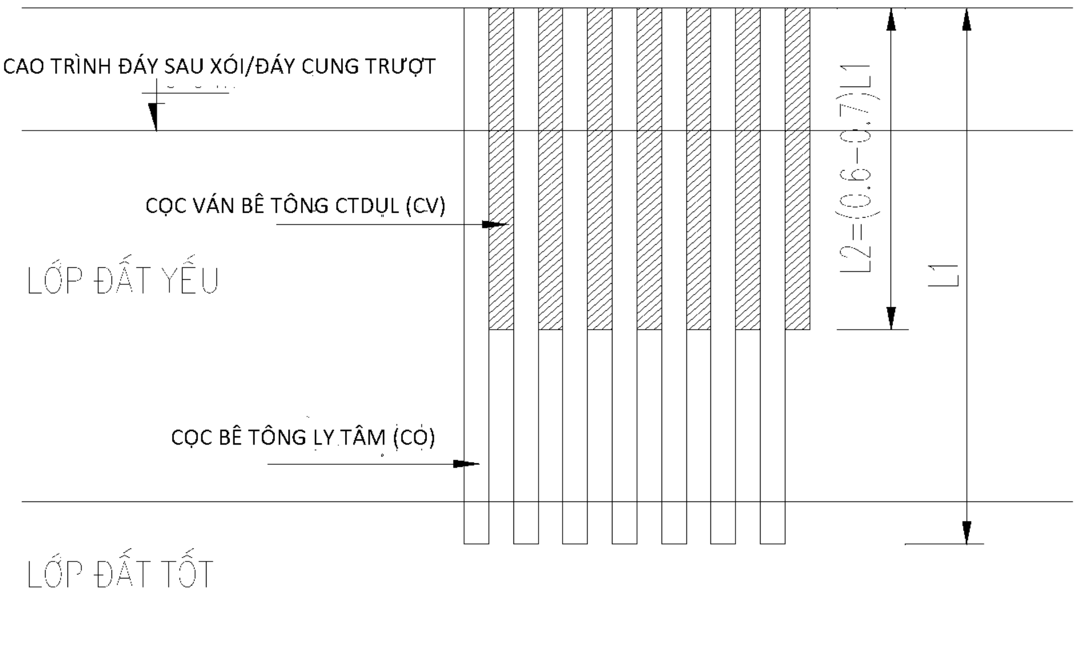


Fig. 2. Preliminary selection of length of semi-continuous pipe-sheet pile wall.

II. Applying Design Calculation to Vam Nao River Embankment Work

2.1. *Description of the Work and Input Parameters*

On April 22nd 2017, at Vam Nao riverside, My Hoi Dong Commune, Cho Moi Districtm An Giang, it has landslide of 160m, penetrating into the mainland more than 30m, causing 16 houses collapsed into the river, affecting 108 households who must relocate urgently. Total damage is estimated about 90 billion (Source: vnexpress https: //vnexpress.net/).

Hydrological data: the highest water level: + 1.65m, the lowest water level: -2.6m; The daily tide level: the highest: + 1.49m, the lowest: -2.58m [9].

From the data in the geological survey records [9], the calculation of the input parameters for the application of embankment wall calculation according to the finite element method using Plaxis 8.2 [1] under the Soft Soil Model Model as follows:

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e} \quad (1)$$

$$\gamma_{unsat} = \frac{(1+w)G_s\gamma_w}{1+e} \quad (2)$$

$$\lambda = \frac{C_c}{2.303} \quad (3)$$

$$\kappa = \frac{C_s}{2.303} \quad (4)$$

Of which: Affecting load: q= 15kN/m^2; name and unit of parameters mentioned in table 1.

Table 1. Parameters of foundation ground.

Parameters	Unit	Clay mut	Dark gray clay	Sandy clay	Note
Model		MSS	MC	MC	MSS: Model Soft Soil
Thichness of ground bed, *H*	m	16.5	2.2	9.3	
Internal friction angle of the ground□□□	degree	0	25	0	
Natural density of the ground under groundwater level, γ_{unsat}	kN/m^3	15.2	18	16.1	
Natural density of the ground above groundwater level, , γ_{sat}	kN/m^3	14.7	20	14.8	
Percolation coefficient according to direction x, k_x	m/day	1.6E-4	0.2	0.3	MC: Mohr-Coulomb
Percolation coefficient according to direction y, k_y	m/day	1.6E-4	0.2	0.3	
Poisson coefficient, □		0.45	0.3	0.3	
Consolidation coefficient, *OCR*		1	1	1	
Natural empty coefficient, e_{init}		2.5	0.8	1.4	
Stickiness of ground, *C*	kN/m^2	17	1	25	
Compression index, C_c		0.76	-	-	
Recoverred compression index, C_s		0.11	-	-	

Table 2. Computational features of combined prestressed reinforced concrete pipe- sheet pile wall (SW400+D700x110)

Parameters	Sign	Unit	Value	Note
Behavior			Elastic	SW400+D700x110: typical product of Beton6 Company
Area of cross section	A_t	m^2	3.70E-2	
Inertia moment	I_t	m^4	2.03E-4	
Vertical hardness	E_tA_t	kN	3.6E+6	
Hardness tolerance	E_tI_t	kNm^2	3.3E-4	
Bending resistance moment	[W]	m^3	4.45E-3	

2.2. *Proposal and Selection of Structural Options*

Based on the proposed conditions of the plan and the actual situation of position, terrain, geology, actual erosion situation of the area, the design proposal is the combined prestressed reinforced concrete pipe- sheet pile wall (Option 2) and comparison of pipeboard – steel sheet pile wall (Option 1) of NSSMS Company -Japan as follows:

Option 1: Use the proposal of D1500x17 +NS-SP-10H pipeboard – steel sheet pile wall made in two rows, L = 23m of NSSMS Company –Japan, see Figure 3 & Figure 4. [10].

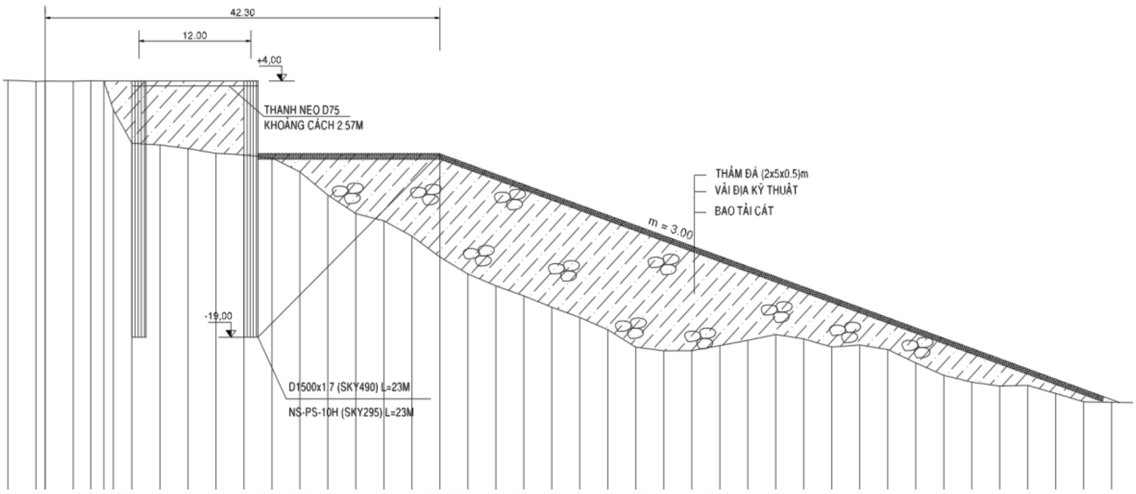


Fig. 3. Cross section jointly arranged with combined pipeboard – steel sheet piles, D1500x17+NS-SP-10H.

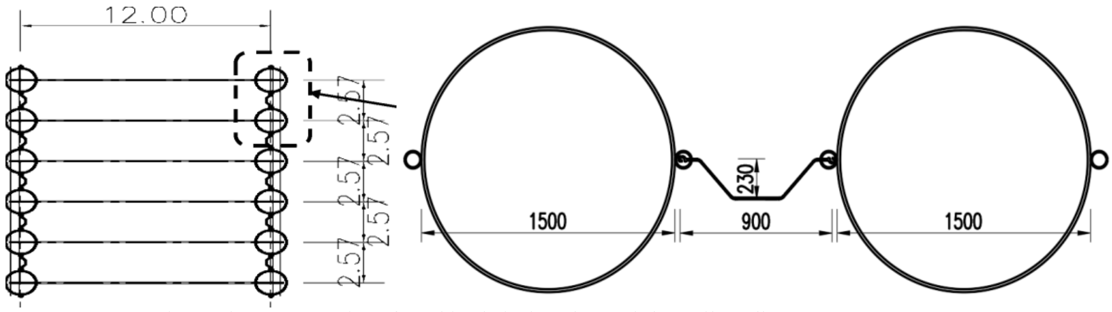


Fig. 4. Plan, cross section of combined pipeboard – steel sheet pile wall, D1500x17+NS-SP-10H

Option 2: Propose option wal structure with prestressed concrete pipe piles D700, length of 25m alternately combined with prestressed concrete sheet piles of SW400, length of 16m with shorter piles, referred to semi-continuous pipe-sheet pile wall, see figure 5 & figure 6.

Top altitude of wall designed as +4.0m bottom altitude of -19.0m. Basic size of Kích SW400 piles as follows: b = 996mm, h = 400mm, t = 200mm, mortice. Connected with prestressed pipe piles of D700, length of 110mm.

To control displacement of the coping and reduce the internal force in the wall arranged with the anchor hole using the reinforced concrete sheets, connect the anchor holes with barrio wall through prestressed cables of 15.2 mm; dead anchor head fixed in the cap beam of the barrier wall, alive anchor head arranged on the concrete sheet of the anchor hole.

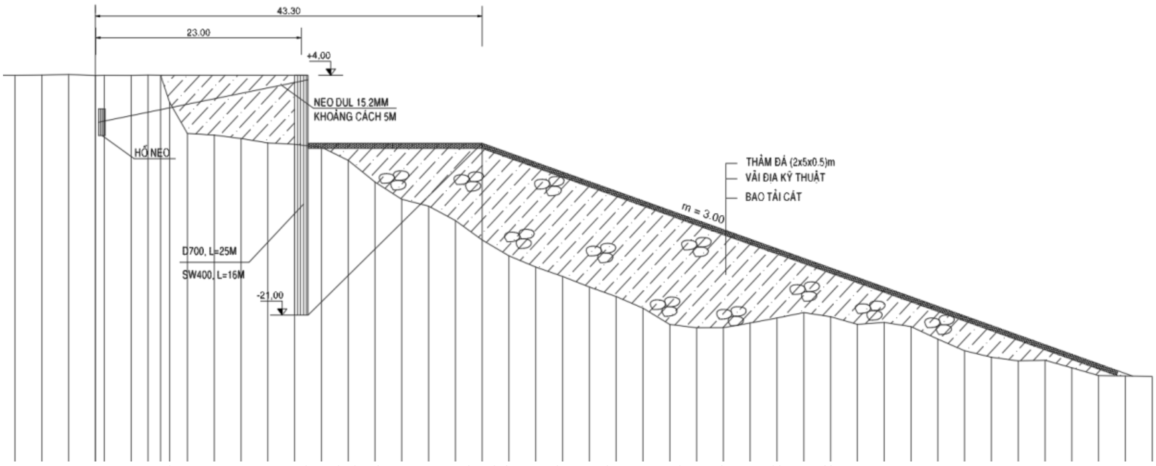


Fig. 5. Cross section jointly arranged with semi-continuous pipe-sheet pile wall, SW400+D700x110.

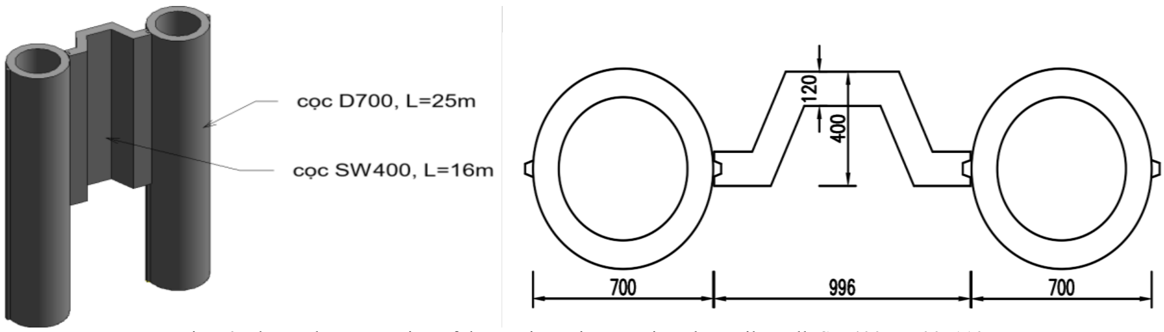
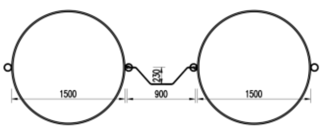
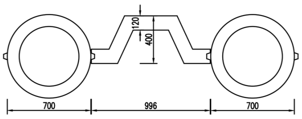


Fig. 6. Plan and cross section of the semi-continuous pipe-sheet pile wall, SW400+D700x110.

Table 3. Comparison of two options of steel pipe-sheet pile wall and semi-continuous pipe-sheet pile wall

Comparative targets	**Option 1:** steel pipe-sheet pile wall D1500x17+NS-SP-10H	**Option 2:** semi-continuous pipe-sheet pile wall (SW400+D700x110)
Cross section of the barrier wall		
Structural features	Including 2 embankment walls of steel pipe-sheet pile with D1500x17,length of 23m alternately combined with NS-SP-10H steel sheet piles, pile length of 23m, distance of 2 walls is 12m. - Weight of steel pile - sheet pile is 120kg/m of steel pipe piles. - It is averagely 19,6m of pipe piles and 18,5m of sheet piles/	Including pre-stressed concrete pipe piles with D700, length of 25m alternately combined with pre-stressed concrete sheet piles of SW400, length of 16m; and concrete anchor holes arranged in 5m/1 hole 23m far from wall. - Weight of pre-stressed concrete pipe pile is

	1m of wall length, equivalent to about 100million/ 1m of wall length .	630kg/1m of pile length. - It is averagely 15,2m of pipe pile and 9,2m of sheet pile/1m of wall length, equivalent to 60 million/ 1m of wall length.
Construction conditions	Construction is more simple than the option 2.	Construction is more complex than the option 1 and weight of pre-stressed concrete pipe-sheet pile is higher.
Maintenance	Have to maintain the wall above the water level.	Don't have to maintain
Safety of the structure	Allowed displacement is high: 15cm (JRA 1996-Japane)	It is allowed for horizontal displacement according to 22TCN 272-05: 38mm [4,6,7,8].
Expense rate	1.0	0.6(SELECTED)

From the above analyzes, it is proposed to choose the option 2 of semi-continuous pipe-sheet pile wall (SW400+D700x110) to analyze the design for the embankment of Vam Nao river.

2.3. *Analysis and Calculation of Semi-continuous Pipe-Sheet Pile Wall*

a. Determining Length of Spun Concrete Piles (CO), L1

Using Geo5 software (Geotechnical software suite modun Sheeting design): enter input data: mechanical & physical properties of ground beds, external load, landfill height, condition of water level, position of anchor line, etc… The results of the program will select pile depth in the ground in the most reasonable way according to the theory of limit balance. After selecting preliminarily the pile length, calculate and check with Plaxis software according to the finite element method.

Result of calculation to select the pile length with Geo5 software is 24.78m. Select the length of spun concrete pile is L1 = 25m (see figure 7).

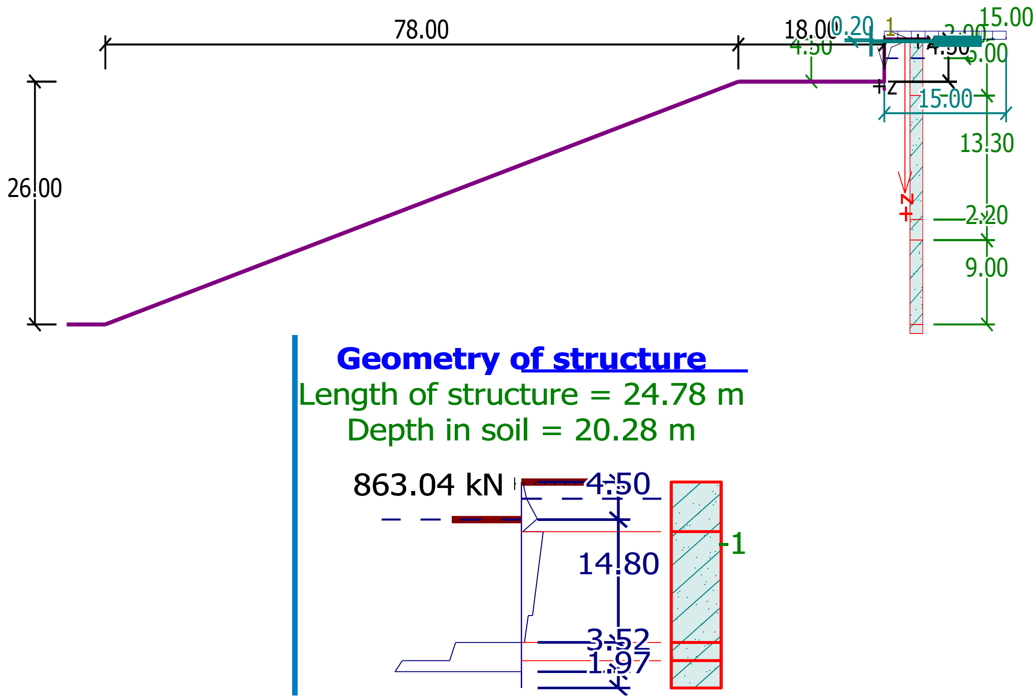


Fig. 7. Calculation model to select spun concrete pile length using Geo5 software [2].

b. Determining length of pre-stressed concrete sheet piles (CV), L_2: Preliminary selection of pile length L_2=0.64L_1= 0.64*25m=16M; calculation and check of length L_2 using Plaxis 8.2 software:

Steps of analysis and calculation:

- Step 1: Natural ground stability to check foundation ground parameters;

- Step 2: Calculation and check of the structure according to construction phases;

- Step 3: Calculation and check of the structure in the exploitation phase;

The results of the above analysis steps: stable coefficient (FS), horizontal displacement of the coping (Ux) and internal force in the pipe –sheet piles (M_{max}; Q_{max}) according to the finite element method using Plaxis.

Some images of calculation model results (Figure 8, 9 and 10) and Table 4:

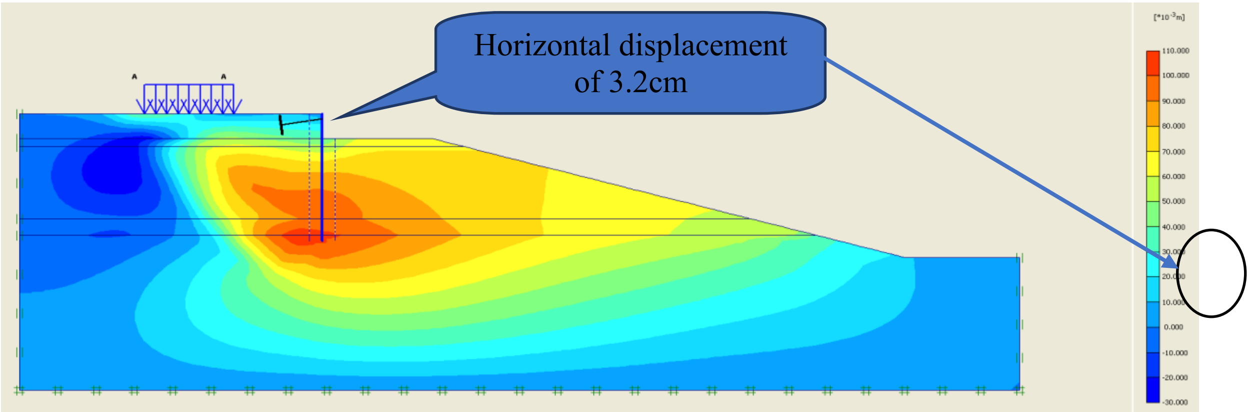


Fig. 8. Displacement of the work, displacement of the coping of 3.2cm<3.8cm.

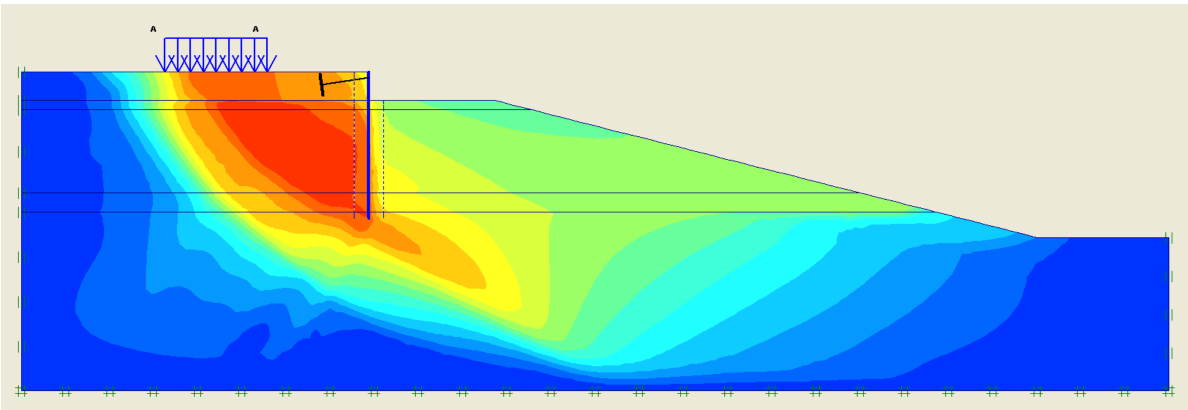


Fig. 9. Shape of overall sliding plane of the work with safety coefficient Msf = 1.565.

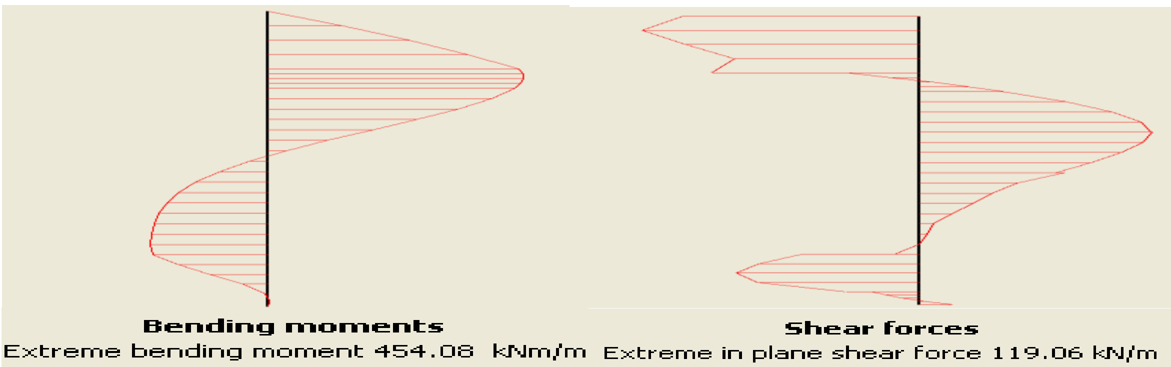


Fig. 10. Diagram of beding moments and shear forces in the barrier wall.

Table 4. Approval of SW400+D700x110 wall structure.

Structure	Calculated moment	Allowed moment	Conclusion
	$M_{max,}$kNm	kNm	
Pile SW400	431.376	450	**Pass**
Pile D700x100	499.489	540	**Pass**

III. Conclusions

From the comments of the above example, it is possible to give some following conclusions:

The solution of wall of spun concrete pipe piles combined with semi-continuous pipe-sheet piles is 40% lower than the steel pipe-sheet pile wall in cost for the embankment of Vam Nao River – An Giang and may be applied for similar works in Mekong Delta.

Determining the depth of with semi-continuous pipe-sheet piles (*L1*) according to the graphic solution method or the finite element method with computer aid such as ProSheet v.2-2 or Geo5,…; propose length of pre-stressed concrete sheet piles, L2 = (0.6÷ 0.7)L1.

Need to adjust the pre-stressed concrete sheet pile structure with only mortice and for spun concrete piple piles, it is required to add gudgeon.

Limitations of research results are only calculated on the model.

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Authors' Profile

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