The Practice of an MSE Wall/Embankment on a Hard Foundation: A Case Study from Phitsanulok, Thailand

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ABSTRACT: The Department of Highways (DOHs), Thailand, designed and constructed a 6m high reinforced earth embankment near Highway No.11 Phitsanulok-Uttaradit in Thailand. Two types of reinforced earth embankment were constructed; on one side, bags of soil were used to construct a Reinforced Steep Slope (RSS) with a 70 degree sloping face and on the other side, a Mechanically Stabilized Earth Wall (MSEW) was constructed with a vertical concrete panel as a facing. The test embankment was 18m long and 15m wide at the top. Three types of polymeric geogrid reinforcements were installed in the reinforced steep slope (RSS) facing and two types of metallic reinforcement were installed in the mechanically stabilised earth wall (MSEW) facing. The polymeric geogrid reinforcement consisted of polyester (PET), high density polyethylene (HDPE) and polypropylene (PP), while the metallic reinforcement consisted of steel wire grid (SWG) and metallic strip (MS). Monitoring instruments such as inclinometers, settlement plates, total pressure cells, standpipe piezometers, vibrating wire strain gauges and fibre optic strain gauges were installed to check the displacement, stresses, excess pore water pressures, groundwater table, and strains in the reinforcing material. PLAXIS 3D (Version 2011) was utilised for the FEM numerical simulations of the embankment. The behaviour of a reinforced soil slope (RSS) and mechanically stabilised earth wall (MSEW) on a hard foundation were observed and compared with the predictions from PLAXIS 3D software, in terms of any lateral and vertical deformation.

1 INTRODUCTION

Many researchers have studied the behaviour of several types of reinforced earth structures on Bangkok soft soil, most of which were built in the premises of AIT campus. Cisneros(1989), Abiera (1991), Shivashankar (1991), Mir (1996), Alfaro (1996), Long (1996), Kabiling (1997), Modmoltin (1998), Wongsawanon (1998), Srikongsri (1999), Visudmedanukul (2000), Voottipreux (2000), Asanprakit (2000), Kongkitkul (2001), Supawiwat (2002), Rujikiatkamjorn (2002), Youwai (2003), Rittirong (2003) , Prempramote (2005), Lai et al. (2006), Tanchaisawat (2008), Tin (2009) and Nualkiang (2011) studied and analysed the behavior of various types of reinforced earth structures and components during their research at AIT.

2 DESCRIPTION OF EMBANKMENT

The Department of Highways (DOHs) in Thailand designed and constructed a 6m high reinforced earth embankment near Highway No.11 (Phitsanulok-Uttaradit) in Phitsanulok Province in central Thailand. The test embankment was 18 m long and 15 m wide at the top. On one side, bags of soil were used to construct a reinforced steep slope (RSS) with face sloping at 70 degrees from the horizontal and on the other side, a mechanically stabilised earth wall (MSEW) was constructed with vertical concrete panels as the facing. Three types of polymeric geogrid reinforcements were installed in the reinforced steep slope (RSS) facing, and two types of metallic reinforcement were installed in the mechanically stabilised earth wall (MSEW) facing. The three types of polymeric geogrid reinforcement were polyester (PET), high-density polyethylene (HDPE) and polypropylene (PP), and the metallic reinforcement consisted of steel wire grids (SWG) and metallic strips (MS). The vertical spacing was 0.5 m and the reinforcement was 5 m long. The grid spacing for MSEW wall was 0.375m for the first layer of reinforcement and 0.5m for the remaining layers. An extensive field instrumentation program was established to monitor the behaviour and performance of the embankment/wall, the geogrid reinforcement and steel reinforcement, and the condition of the subsoil. Instrumentation was installed into the subsoil before the embankment/wall was constructed. Monitoring was carried out during construction and after it has been completed. The monitoring instruments installed to check the vertical and horizontal displacements, stresses, excess pore water pressure, depth to the groundwater table, and strains in the reinforcing material included inclinometers, settlement plates, total pressure cells, standpipe piezometers, vibrating-wire strain gauges and fibre optic strain gauges. These instruments included 5 inclinometers, 45 settlement plates, 6 total pressure cells, 5 standpipe piezometers, 2 reference benchmarks and 5 instrument houses. In addition, two observation wells were installed to measure fluctuations in the depth to the groundwater table. The plan and cross section of the MSE wall/embankment with the location monitoring instruments are shown in Figs. 1 and 2, respectively.

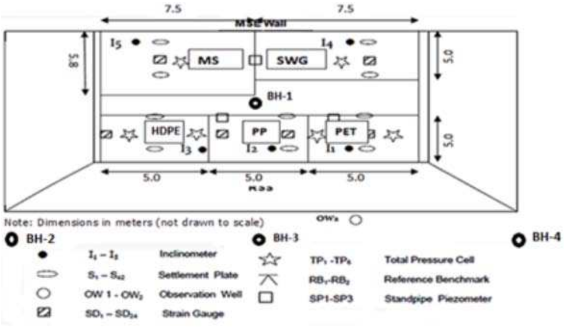

Fig. 1 Plan of MSE wall/embankment

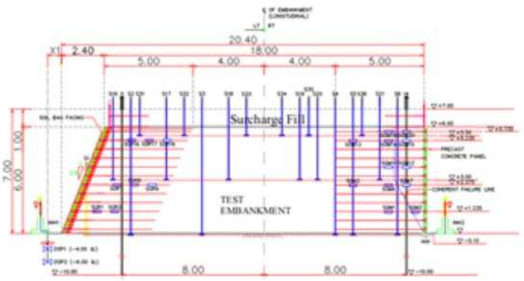

Fig. 2 Cross section with instrumentation

3 COMPONENTS OF THE MSE WALL

The backfill material prepared for this embankment consisted of 50 % of lateritic soil mixed with 50 % of silty sand by volume. The backfill material was classified as poorly graded sand (SP). In addition, polymeric and metallic materials were used as reinforcing materials; they consisted of metallic strips, steel wire grids, polyester, polypropylene and high density polyethylene. To support the MSEW facing, precast segmental blocks, 1.5m by 1.5m by 0.15m were used. Details of the backfill material, reinforcements, and the precast concrete panel and their properties are tabulated in Tables 1, 2 and 3, respectively.

Table 1. Properties of backfill material

Atterberg Limit Test	LL = 20.8%, PL=17.3%, PI=3.5%.	
Sieve Analysis Test	Sample No. 1 Percent finer (#200 sieve) = 0.94% Cu = 40, Cc = 0.34 Sample No. 2 Percent finer (#200 sieve) = 0.14% Cu = 42.86, Cc = 0.55	
Unified Classification	Poorly graded sand (SP)	
AASHTO Classification	A-2-4(0)	
Compaction Test	Maximum dry density ($\gamma_{d,max}$) = 19.62 kN/m^3 Optimum water content (OMC) = 7.8 %	
California Bearing Ratio (CBR) Test	CBR = 50.5%	
Direct Shear Test	Friction angle = 42 degrees cohesion = 80 kPa	
Triaxial Test (CU test)	Test No. 1	Friction angle = 32.8 degrees cohesion = 0 kPa
	Test No. 2	Friction angle = 37 degrees cohesion = 20 kPa

Table2. Properties of reinforcements

Material Name	Tensile Strength (kN/m)	Thickness (mm)	Normal Stiffness, EA (kN/m)	Type
Metallic Strip (MS)	277.6	4.00	88,000	-
Steel Wire Grid (SWG)	128.1	6.00	35,000	-
Polyester (PET)	83.6	1.50	925	Miragrid GX80/30
Polypropylene (PP)	91.9	1.45	1,360	Secugrid 80/80 Q1
High-Density Polyethylene (HDPE)	85.8	1.91	1,320	TT090 SAMP

Table 3. Properties of precast concrete panel

Parameter	Name	Value	Unit
Type of behaviour	Material type	Elastic	
Normal stiffness	EA	42,000,000	kN/m
Flexural rigidity	EI	78,500	$kN.m^2/m$
Equivalent thickness	d	0.15	M
Weight	w	3.6	kN/m/m
Poisson's ratio	υ	0.15	-
Model		Plate	

4 NUMERICAL SIMULATION

PLAXIS 3D (Version 2011) was utilised as the 3D FEM numerical simulation tool for this embankment. To minimise the effects of test embankment boundaries, the PLAXIS 3D discretisation was formulated and the boundary conditions were specified at distances of twice the length and width of the reinforced embankment in the x and y directions, respectively, and four times the height of the reinforced embankment in the z direction. A finite element mesh was created to carry out a finite element analysis of the embankment using PLAXIS 3D, and the material properties of the embankment components were established (Table 4). The generation of an appropriate finite element mesh and the generation of properties and boundary conditions on an element level were automatically performed by the PLAXIS mesh generator based on the input of the geometry model.

Table 4. Material properties and conditions

Soil Description	Model	Condition	γ_{sat} (kN/m^3)	γ_{unsat} (kN/m^3)	υ	E (kPa)	c' (kPa)	Φ' (°)	k_x (m/day)	k_y (m/day)
Backfill	M-C	Drained	22.7	21	0.3	20,000	10	37	0.8	0.4
Clayey sandy silt to clayey silty fine sand	M-C	Drained	19	17	0.3	18,000	1	33	0.001	0.0005
Medium dense clayey sand	M-C	Drained	18	16	0.3	37,500	5	34	0.001	0.0005
Stiff to very stiff clay	M-C	Undrained A	17	15	0.35	40,000	50	24	0.00002	0.00001
Very stiff clay	M-C	Undrained A	17	15	0.35	50,000	80	26	0.00004	0.00002
Hard clay	M-C	Undrained A	17.5	15.5	0.35	80,000	100	28	0.00004	0.00002

5 RESULTS AND DISCUSSION

The lateral deformation of each type of polymeric reinforcement (i.e., PET, PP and HDPE) on the RSS side and each type of metallic reinforcement (i.e., MS and SWG) on the MSEW side were obtained from field measurements using inclinometers, and then compared to the numerical simulation results 186 days after construction had been completed. Inclinometers I3 and I5 refer to those inclinometers installed in the PE and MS, respectively. Larger deformation occurred on the top of the embankment after the 1.2-m-thick surcharge was added, and this was confirmed as the embankment tilted at the top. Similarly, the maximum settlement at the base of the embankment (Level 0.00 m) ranged from 60 to 80 mm 186 days after construction was completed. The foundation compressed more towards the facing for the PE-MS section, while the overall compression of the embankment (Level 0.00 m to Level 5.50 m) varied between 20 to 40 mm, for the PE-MS section.

6 CONCLUSIONS

- The RSS facing deformed much more than the MSEW facing because the polymeric reinforcement was not as stiff as the metallic reinforcement. The reinforcing materials can be listed in the following descending order in terms of stiffness: metallic strips (MS), steel wire grids (SWG), polypropylene (PP), high-

density polyethylene (HDPE) and polyester (PET).
- The lateral and vertical deformation of both facings, albeit with different types of reinforcement, agreed with those predicted from the numerical simulation using PLAXIS 3D.
- Although the embankment was made up of mixed soils, and abrupt changes were noted in the soil profile at the field site, the simulations from PLAXIS 3D could simulate the overall behaviour of the embankment and there was good agreement between the field measurements and simulation results.

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