MODEL STUDIES ON THE SETTLEMENT OF REINFORCED-EMBANKMENT WITH GEOTEXTILES AND PLASTIC-SACK WASTES OVER SOFT SOILS

UJI MODEL PENURUNAN TIMBUNAN DI ATAS TANAH LUNAK DENGAN PERKUATAN GEOTEKSTIL DAN KARUNG PLASTIK

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ABSTRACT

The simple embankment was modelled in laboratory to investigate the settlement behaviour and to evaluate number of reinforcement layers. For the study, two type of reinforcement materials were used that is woven geotextiles and plastic-sack sheets. In laboratory, the dimension of embankment was scaled in 1:10, but thickness of the reinforcement materials was scaled in 1:1. The embankment was designed from a mica-flexi glass to yield a rigid model. The research results show that the settlement of embankment with reinforcement reduced significantly with increasing the number of reinforcement layer. Among the reinforcement used, plastic-sack wastes was effectively to reduce the settlement. Addition of reinforcement beneath the embankment was able to retain and delay the rate of failure
Keywords: settlement, embankment, soft soils, reinforcement, geotextiles, plastic sacks.

ABSTRAK

Model sederhana timbunan diuji di laboratorium untuk mempelajari karakteristik penurunannya di atas tana lunak baik tanpa dan dengan perkuatan geotekstil dan karung plastik dan mengevaluasi jumlah lapisan perkuatan. Model laboratorium timbunan dibuat dalam skala fisika 1:10 , sedangkan ketebalan bahan perkuatan dibuat dalam skala 1:1. Timbunan dibuat dari bahan mica-flexi glass guna memperoleh model yang kaku. Hasil penelitian menunjukkan bahwa penurunan timbunan yang diberi perkuatan berkurang dengan bertambahnya jumlah lapisan perkuatan. Perkuatan dengan menggunakan karung plastik lebih efektif untuk mengurangi penurunan. Penambahan perkuatan dibawah timbunan dapat menahan dan memperlambat laju keruntuhan.
Kata-kata kunci: penurunan, timbunan, tanah lunak, perkuatan, geotekstil, karung plastik.

INTRODUCTION

In recent year, plastic wastes have been a worldwide problem. Plastics were comprised of fibers that could be made from polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), or polyvynil (PV). Environmental issues have driven interest to utilize these plastic wastes as alternative construction material. One promising reuse of these wastes lies in soil reinforcement. Extensive studies have been reported in the literatures that indicate the use of plastic waste fibers in soil can enhance the shear strength, tensile strength, durability, load-bearing capacity, and slope stability (Cavey et al., 1995; Consoli et al., 2002; Messas et al., 1998; Ghiassian et al., 2004; Loehr et al., 2000). However, very little research has been done to apply the plastic waste as reinforcement for embankment over a soft soil.

Embankment or earth fill construction is often constructed to serve highway traffic rest on soft subsoil that has low bearing capacity. Theoretically, the embankment will settle subjected to increasing of the load acting on the crest of embankment and the dynamic loading of traffic. One of the methods to reduce the settlement is to place reinforcement beneath the embankment or layered in soft subsoils.

Studies on performance and failure deformation of embankment with and without geotextiles reinforcement have been investigated by many researchers such as Jewell (1988), Chai et al. (2002), Bergado et al. (2002), Muntohar (2004). Some researches have been implemented in full scale or field work and microstructure embankment in laboratory. Research conducted by Chai and Bergado (1993) in full-scale model showed that at the acting or service condition, placement of the geogrid reinforcement beneath of embankment will only contribute lessen factor of safety (*FS*) of the embankment. Further, the effect on the reduction of deformation was not significant. However, other researcher, Rowe et al. (1984) denoted a different result that implies the geotextiles reinforcement induces the failure behavior of embankment directly. As stated by Tjandrabirawa et al. (2002), placement of geotextiles beneath the foundation would increase the bearing capacity of the foundation as 241% compared with the unreinforced soil foundation. Some researchers stated that the geotextiles reinforcement acting in soil foundation would be affected by geometrical, placement and the materials properties of the geotextiles (Chai et al., 2002; Krishnaswamy et al., 2000; Utomo, 2004).

This paper discusses a research result of scaled embankment in laboratory over on soft soils foundation with and without reinforcement. The main objective of this study is (1) to study the settlement characteristic of the embankment with and without reinforcement, (2) to evaluate and compare number of reinforcement layers beneath the embankment.

DESIGN OF EXPERIMENT

Materials Used

Soils

The soils used for foundation of the model were taken from Kasihan, Bantul, Yogyakarta. The specific gravity of soil specimen was 2.64. Based on the particle size distribution in Figure 1a, the soil specimen comprised of 29% clay, 64% silt, and 7% sand fraction. The consistency limit of the soil specimen was 72.5%, 36.4%, 36.1% for liquid limit, plastic limit and plasticity index respectively. According to the Unified Soil Classification System, the soil specimen was categorized as high plasticity silty-clay and symbolized with MH (see Figure 1b).
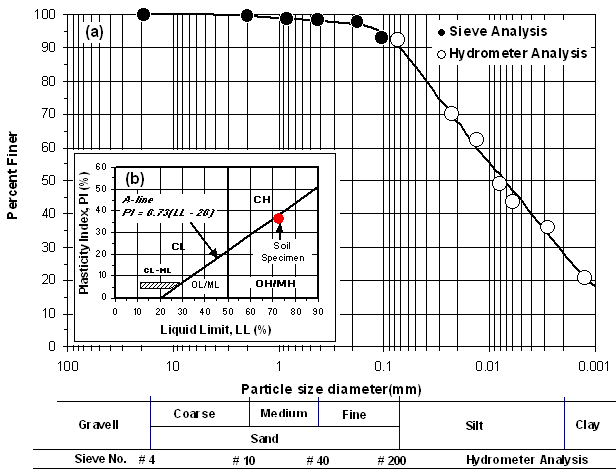
Figure 1. (a) Particle size distribution of the soil used in this study (b) Plasticity chart

Table 1. Tensile strength test result of the plastic waste used in this study

Parameter	Specimens No.		
	1	2	3
Strain at failure (%)	15.4	15.6	12.3
Tensile strength at failure (kN/m)	7.56	6.72	6.56

Reinforcement

The geotextiles used in this study is woven type *Hate-Reinfox 385250 XT*. The allowable tensile strength is about 53 kN/m. The plastic wastes was used in the present investigation were obtained from available polypropylene plastic-sack wastes.

Table 2. Test program in the study

Code	Specimens		CT	LDT
NR	Non reinforcement		●	●
	Reinforcement:			
G-1	geotextile::	1 layer	○	●
P-1	plastic wastes:	1 layer	●	●
G-2	geotextiles:	2 layers	○	●
P-2	plastic wastes:	2 layers	○	●
G-3	geotextiles:	3 layers	○	●
P-3	plastic wastes:	3 layers	○	●

Note: CT = one dimensional consolidation test; LDT = load-deformation test; ● = tested; ○ = not tested

The plastic sack sheets were tested for tensile strength using *Uni-versal Tensile Testing Machine* from Hung Ta. The result of ten-sile strength test is presented in Table 1. In this research, number of reinforcement layers was varied 1, 2, and 3 layers beneath the embankment.

Embankment Model

The model embankment was fabricated from flexi-glass. Dimension of the embankment model was designed 0.04 m in he-ight, length of the top was 0.11 m, and length of the foundation was 0.23 m. The flexi-glass embankment was filled with uniform sand whose the unit weight was about $\gamma = 14.4$ kN/m³. The em-bankment was placed upon on the soft-clay container. The size of the container was 1 m in length, 0.2 m in width, and 0.5 m in hei-ght as shown in Figure 2. The model was equipped with dial gauge indicator to measure vertical defor-mation when the embankment was loaded. Since scale of the em-bankment model is relatively small (1g), then additional loading was performed to achieve failure.
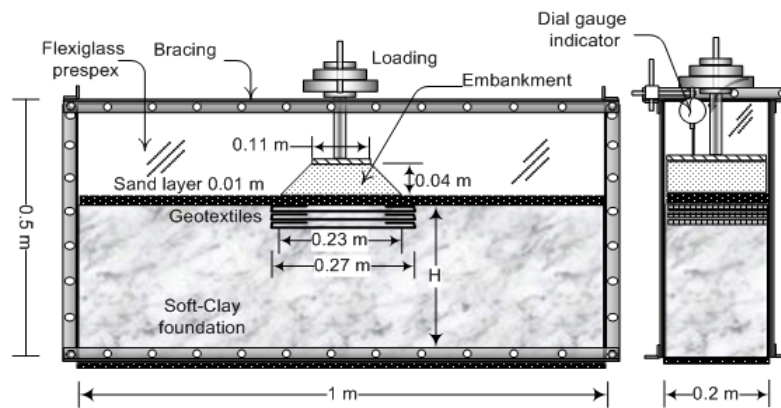
(a)
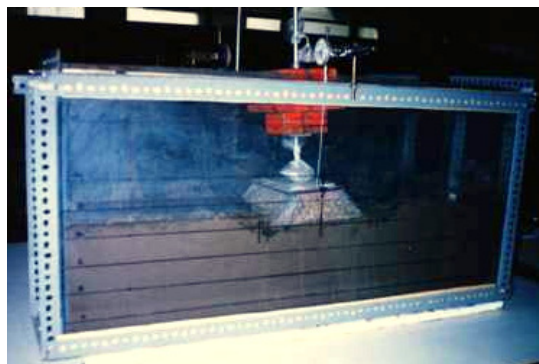
(b)

Figure 2. The embankment model in laboratory for the study (a) sketch of the model (b) photograph the model

Preparation and Testing Procedure

The tests program for this study is summarized in Table 2. The soft-clay soil foundation was prepared by means filling the soil container with the soil which has liquid limit LL = 72.5% and bulk volume weight γ_b = 15.8 kN/m^3. The soil was compacted to obtain the designed thickness. The clays soil thickness (H) was designed to 0.2 m. Sand layer was deployed 0.01 m over the soft clays foundation as horizontal drain. Then, preloading was performed for 3 days to obtain a uniform thickness. The preloading was equivalent with surcharge pressure about 1.0 kPa – 1.5 kPa.

After preloading, soil samples were taken at the a half of soil thickness for consolidation test. Reinforcement, geotextiles and plastic waste, was placed 1 cm beneath the embankment. The vertical spacing between layers was 0.01 m. Length of the reinforcement was 0.02 m longer at each ends than the length of embankment foundation. Number of reinforcement layers was varied from 1, 2, and 3 layers. Embankment model was placed at the center of the soil foundation (figure 2). Additional load was applied incrementally until the embankment collapsed. Each loading sequence was finished after 24 hours or there was no further deformation. For each loading, vertical deformation of the embankment was measured by dial gauge indicator, which instrumented on top of embankment.

Data Analysis

The parameters found from the experiments were vertical deformation of the embankment without and with geotextiles reinforcement, load at failure, and elapsed time to reach failure. Based on this observed parameter, the data was presented in some graphical presentation as follow: (1) relationship between load and settlement, (2) relationship between settlement and elap-sed time.

RESULTS AND DISCUSSIONS
Consolidation behavior

In this study, consolidation and loading test were performed for soil specimens at 0.1 m depth. Table 3 presents parameter observed in consolidation test. According to the results of consolidation test, the overconsolidated ratio (OCR) of the soil specimens are greater than one (OCR > 1). Hence, the soil specimens can be categorized as over consolidated (OC). The degree of compressibility of soft clay soil will be greater if the compression index in laboratory (C_c') have a tendency to increase.

Table 3. The parameter of consolidation test of soil specimens

Parameter	Specimen 1	Specimen 2
σ'_c (kPa)	8.7	12.0
σ'_o (kPa)	1.58	1.53
OCR	5.51	7.84
C_c	1.09	1.37
C_c'	0.52	0.69
C_r	0.0704	0.0724
e_o	1.89	2.07

Note : σ'_c = pre consolidation pressure, σ'_o = effective vertical stress, OCR = over consolidation ratio = σ'_c /σ'_o', C_c = compression index, C_r = recompression index, C_c' = laboratory compression index, e_o = initial void ratio

However, in-situ compressibility was evaluated from in-situ compression index (C_c) values. Based on the C_c values, the soil specimen can be classified into medium to very soft clay soil since the C_c is greater than one (C_c > 1). The consolidation

behavior of the soil specimens are illustrated in figure 3. The coefficient of consolidation (C_v) and modulus of volume change (m_v) were varied with the applied pressure (σ'). The figure is alluding to show that clay soil was very compressible soil since the m_v value decreased rapidly from 5.7 x 10^{-6} m^2/kN to 1.5 x 10^{-6} m^2/kN when the pressure was increased from 2.5 kPa to 5 kPa (figure 3c).
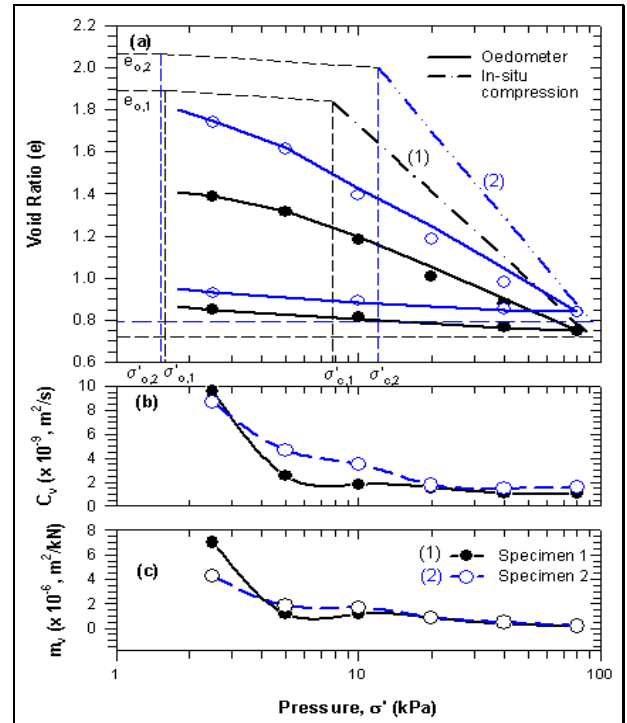

Figure 3. Consolation characteristic of the soft soil foundation

Settlement characteristics of the reinforced-embankment

Figure 4 and 5 depict relationship between surcharge pressure and settlement of the unreinforced and reinforced embankment with geotextiles and plastic wastes respectively. Figure 6 and 7 illustrate the embankment deformation after failure for geotextiles and plastic wastes reinforcement respectively. Since the embankment model was designed as rigid model, the embankment rotate to one side of length when the embankment collapsed. Typical of the failure can be identified as local to general shear failure.

The load - deformation curves in figure 4 and 5 show that elastic deformation occurred by increasing of surcharge pressure up to 1.6 kPa. A fully-plastic deformation was attained if the surcharge pressure was greater than 4.2 kPa. According to the load pressure that caused plastic deformation at 4.2 kPa, the settlement of the embankment without reinforcement approached 30.4 mm or about 13.2% of embankment foundation (b_f = 230 mm). For the reinforced embankment with geotextiles, the settlement at plastic deformation are 19.2 mm, 17.1 mm, and 16.04 mm for one layer reinforcement (G-1), 2 layers reinforcement (G-2), and 3 layers reinforcement (G-3) respectively. While for the reinforcement embankment with plastic sack wastes, the settlement reduce to 22.5 mm, 15.6 mm, and 14 mm for one layer reinforcement (P-1), 2 layers reinforcement (P-2), and 3 layers reinforcement (P-3) respectively. In general, it can be said that reducing of settlement ranges from 37% to 49% if the embankment was reinforced with geotextiles. Meanwhile, for the embankment reinforced with plastic wastes, the settlement reduces about 26% - 54% (see figure 8).
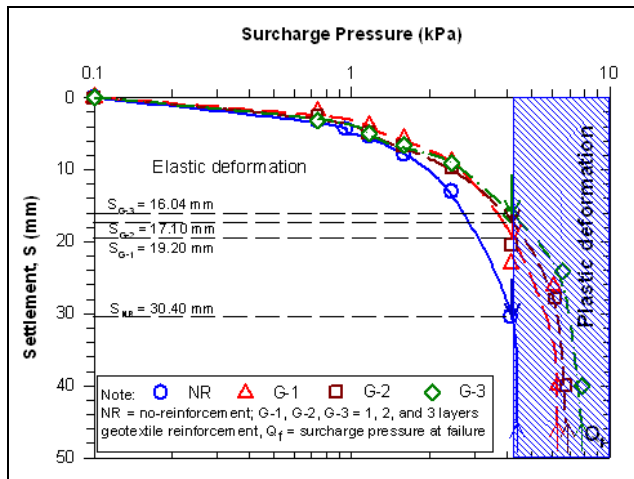
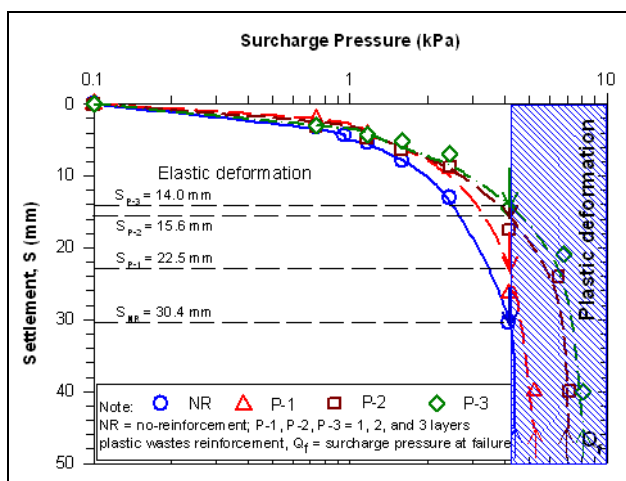Figure 4. Surcharge pressure and settlement curve for geotextiles reinforcement

Figure 5. Surcharge pressure and settlement curve for plastic wastes reinforcement

Figure 6. Failure of the reinforced embankment with geotextiles

Time and Settlement Characteristics

In this study, the load was applied incrementally every 24 hours until collapsing of the embankment was reached. The elapsed time needed to cause a failure can be defined to indicate rate of settlement of the embankment. Figure 9 illustrates rela-tionship between elapsed time and vertical settlement of the em-bankment with and without reinforcement. For non re-inforcement embankment (NR), the embankment collapsed when plastic deformation started to take place. The time failure was about 7 days (10577 minutes). Different behaviors were ob-served for reinforced embankment. After reaching plastic de-formation state, the embankment can stand until a failure was reached. In general, the embankment with one layer rei-nforcement collapsed at 1 – 2 days after the plastic state. For two and three layers reinforcement, the time of failure range from 4 -6 days and 7 – 9 days after plastic state for two layers and three layers reinforcement respectively. This figure shows that the addition of reinforcement in soft soil enhances the ability of embankment to retain the applied load

Based on the illustration in figure 5 and 9, the deformation rate of the non reinforcement embankment at elastic defor-mation can be estimated about 4.34 mm/day. For the embank-ment with geotextiles reinforcement, the deformation rate was estimated about 2.74 mm/day, 2.44 mm/day, 2.29 mm/day for one layer, two layers and three layers reinforcement res-pectively. While for the embankment with plastic-sack wastes reinforcement, the elastic deformation-rate was about 3.25 mm/day, 2.23 mm/day, and 2.0 mm/day respectively for one layer, two layers, and three layers reinforcement respectively.

In figure 8, embankment settlement decreases with increasing the number of reinforcement layers in soft soil foundation. According to the figure, two layers geotextiles reinforcement is sufficient to reduce the settlement. Additional geotextiles layers slightly reduce the settlement. Different characteristic was observed for reinforced embankment with plasticsack wastes. The settlement is likely to decrease sig-nificantly when the embankment was reinforced with three la-yers plastic wastes. Further layers seem to be a little reduction of the settlement. This characteristic indicated that plastic sack waste was acting effectively as reinforcement materials. How-ever, one should consider durability and endurance of the plastic sack waste which is possible lower than geotextiles materials.

Reducing of the vertical settlement indicated that the tensile strength of reinforcement materials contribute to against the working load. As a result, the embankment can retain further plastic collapse. This behavior was possible to occur owing to thickness of the reinforcement materials was not scaled. Hence, the reinforcement materials were stiffer due to the model. This characteristic indicated that the soil was fully reinforced. This condition was also observed by Jewell (1988). According to the study using finite element method, Bergado et al. (2002) ex-plained that application of a high strength geotextiles could re-duce plastic deformation considerably for soft clay deposit.
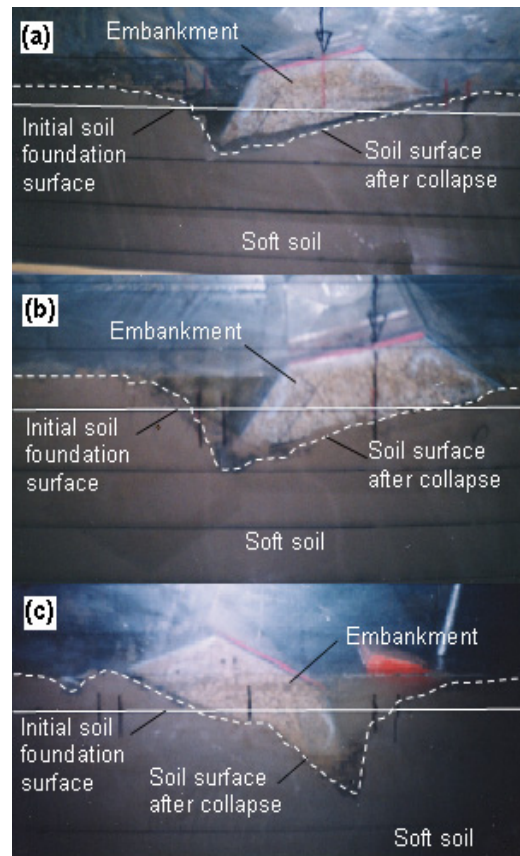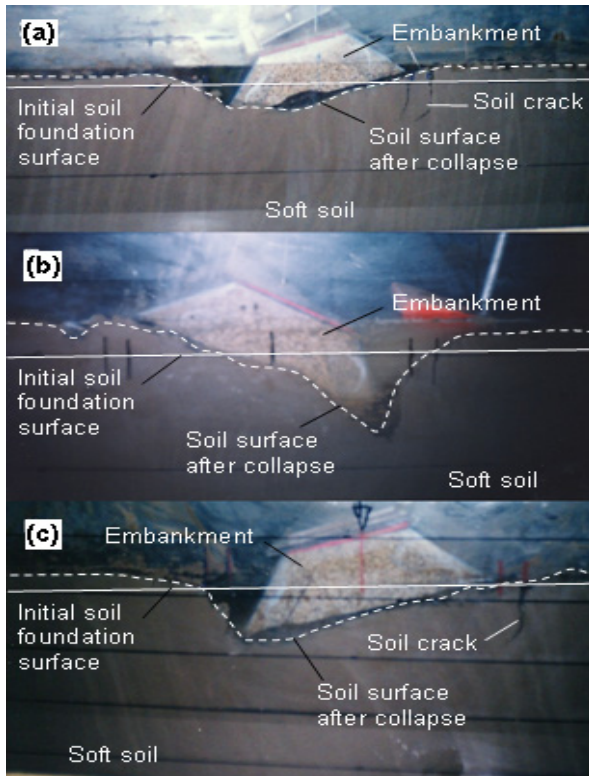
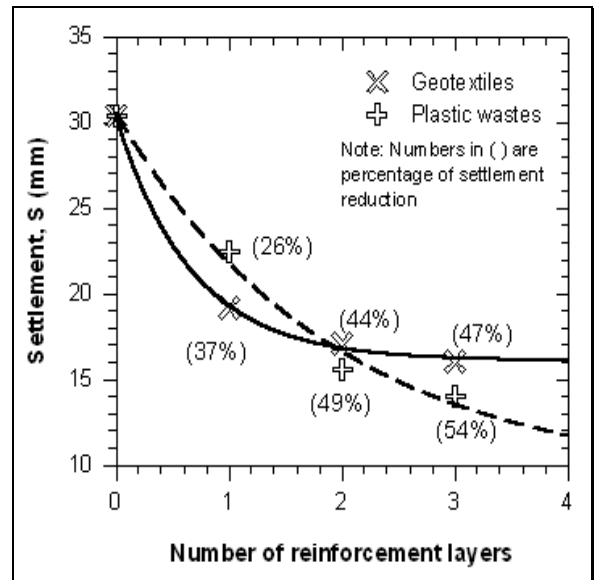Figure 7. Failure of the reinforced embankment with plastic wastes

Figure 8. Relationship between settlement and number of reinforcement layers
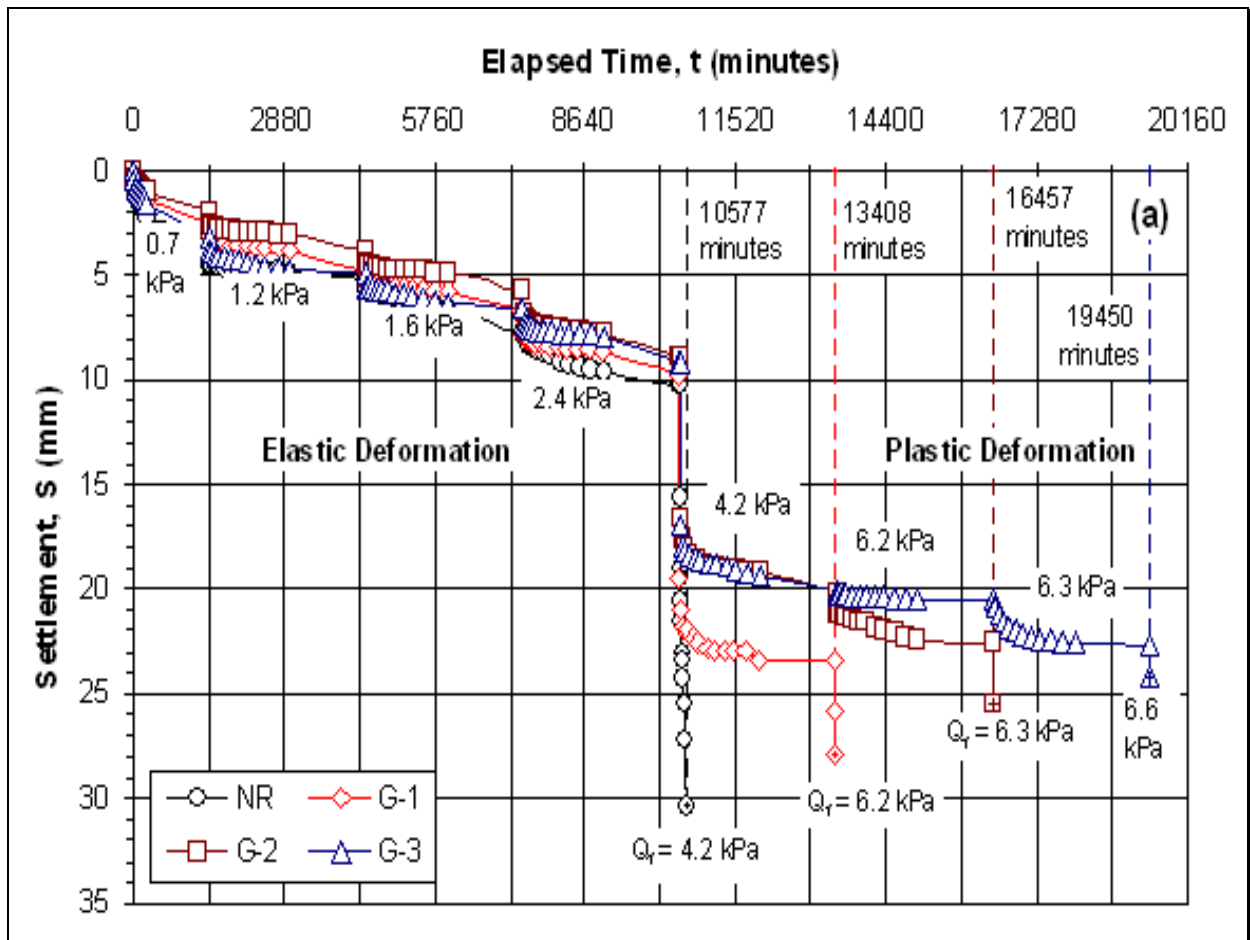

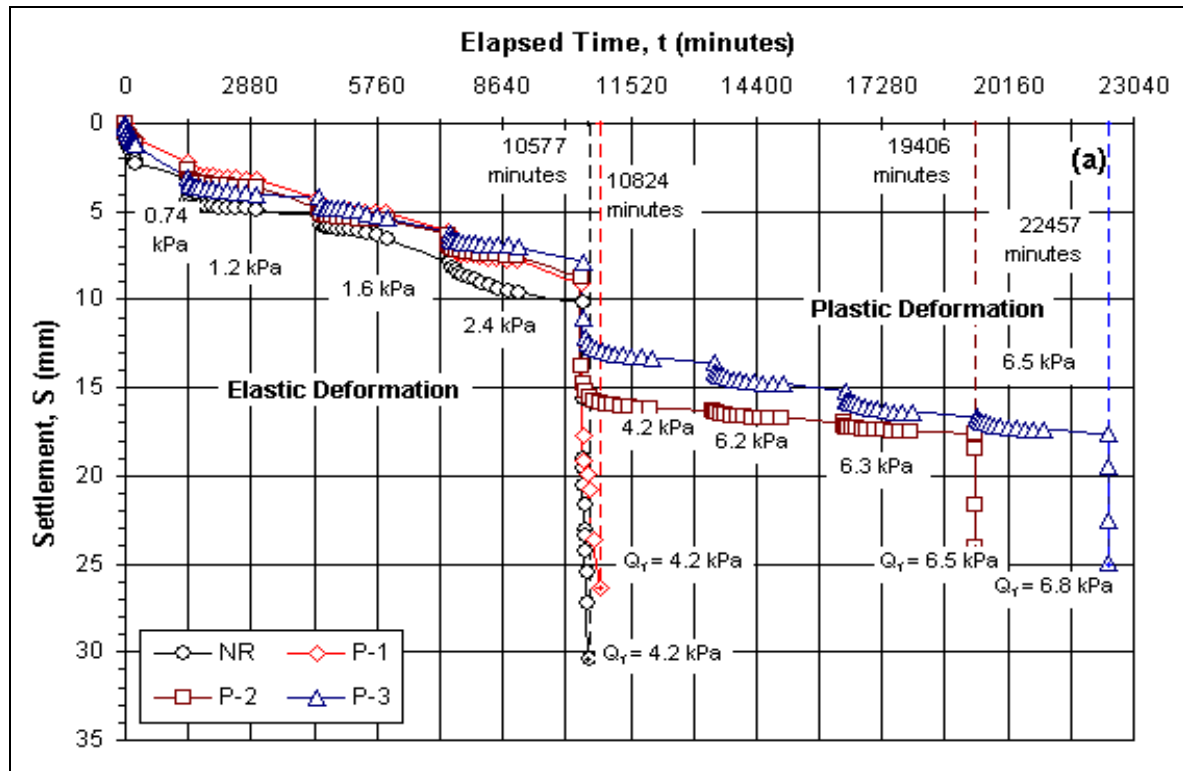Figure 9a. Relationship between settlement and elapsed time (a) embankment with geotextiles reinforcement

Figure 10b. Relationship between settlement and elapsed time (b) embankment with plastic-sack wastes reinforcement

CONCLUSIONS

Based on the results and discussion of the research carried out, conclusions can be drawn as follows:

1. Geotextiles and plastic sack wastes reinforcement in soft clay soils contributes a significant reduction in settlement of embankment if compare to embankment without reinforcement.
2. The settlement of embankment with reinforcement decrease with increasing of number of reinforcement layers. Both of the reinforcement materials, embankment with plastic-sack wastes reinforcement was effectively to reduce settlement if compare with geotextiles reinforcement. However, two layers geotextiles reinforcement was sufficient to reduce the settlement.
3. Addition of reinforcement beneath the embankment was able to retain and delay the failure rate of the embankment.

ACKNOWLEDGEMENT

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