

EFFECT OF NATURAL RUBBER LATEX ON THE COMPRESSIVE STRENGTH AND DURABILITY OF CEMENT STABILIZED SOIL

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Received: July 10, 2019; Revised: January 16, 2020; Accepted: January 18, 2020

Abstract

This research studied the effect of natural rubber latex on the compressive strength and durability of cement stabilized soil. Cement content used in this study was 3% by weight of soil. Water/rubber ratios were 100:0, 90:10, 85:15, 80:20, 75:25 and 70:30 by weight. The influence of wetting and drying cycle on the durability of cement stabilized soil was investigated in this study. Test results show that using natural rubber latex properly can improve compressive strength and durability of cement stabilized soil. The outcome of the study therefore, identifies and indicates the level of efficiency and importance of using appropriate quantity of nature rubber latex in the cement stabilized soil, especially in the areas of wetting and drying durability.

Keywords: Cement stabilize soil, natural rubber latex, compressive strength

Introduction

Soil is a natural material which can be found in all places. The engineering properties of soil depend on various factors, especially its original source and environment. Nowadays, a good quality soil for base/subbase applications is scarcely found due to the increasing of infrastructure constructions that consume a lot of soil volume. Therefore, it is necessary to use the available soil around the construction site. However, its basic engineering properties often do not meet the specification for pavement materials specified by the local authorities. Hence, the soil improvement technique is required. Soil improvement techniques basically

used in the present consist of compaction, stabilization, reinforcement and consolidation.

Cement stabilization is one of the most common soil improvements concepts, which reduces the plasticity index (PI) of soil and results in better soil compressive strength (Terrel *et al.*, 1979).

Hogentogler (1938) reported that the improvement of the soil properties is a process that makes the natural soil more resistant to the deterioration and more bearing load capability. The soil can be improved by mixing with cementitious binder, which is either in liquid or powder form and followed by the compaction method.

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Terrell *et al.* (1979) explained that adding Portland cement into the soil could change the properties and structure of the soil. However, the properties of those soil improvements might not be the same even though the soil has the same physical properties. Although the same cement content is used, the different chemical properties affected the soil compressive strength may not be the same. The chemical composition in cement had a significant effect on the compressive strength of cement stabilized soil.

Mitchell and Jack (1966) described the structure of the soil stabilized by cement that the reaction of cement hydration changes the composition of the soil structure. The cement gel is infiltrated into the voids between the soil particle and releasing the lime. Lime reacts with SiO_2 and Al_2O_3 that are present in the soil. The hydration product from the cement reaction spreads along the soil skeleton. As a result, the strength of the soil cement stabilized increases as increasing in curing time.

Although the treatment of soil with cement is a normal option for road bases/subbases materials, its brittle behavior under compression is normally found. Furthermore, there are some researches reported that using cement in a pavement base/subbase structure could be considered as the source of shrinkage cracking (Bahar *et al.*, 2004). Therefore, the ductile behavior and toughness of pavement materials need to be improved to prevent the sudden failure due to traffic load.

The natural rubber latex has high flexibility properties, which can mix well with water, thus allowing the soil compaction to be effective. Natural rubber latex is a lubricant liquid which allows the soil particles move easily into the voids and make the soil denser. Another advantage of using natural rubber latex with cement is to increase the toughness behavior (Liu *et al.*, 2011). Therefore, it is interesting to apply the combined binder cement and natural rubber for improving the soil properties.

However, the limited knowledge on this technique still remains a barrier for using it in road construction.

The objective of this research is to study the strength and durability improvements of natural rubber latex and cement to improve the soil strength to meet the requirement of the Department of Highways, which unconfined compressive strength (UCS) of subbase soil cement-stabilized under the modified compaction of 1,750 kPa for 7 days curing (DOH, 1989).

Martials and Methods

Lateritic soil samples were collected from a borrow pit in Maung district, Nakhon Ratchasima province, Thailand. It was composed of 5.10% fine-grained particles and 94.91% coarse-grained particles in which 67.61% is gravel and 27.30% is sand. The specific gravity of soil is 2.78. The liquid and plastic limits are 21% and 7.5%, respectively. According to the Unified Soil Classification System (USCS), the lateritic soil was classified as well-graded gravel with silt and sand (GC-GW). The grain size distribution curve is shown in Figure 1 and its basic properties are summarized in Table 1. According to the local road authority specifications for subbase (DOH, 1989), this lateritic soil does not meet the requirement of the local standards. It is therefore required to mix with the high quality material to be considered as a pavement subbase or fill material.

Cement content (C) of 3% by weight of soil was used to stabilize the lateritic soil/natural rubber latex blends in this study as this content is commonly applied in field stabilization in Thailand.

The natural rubber latex was supported by Rubber Authority of Thailand (RAOT). Dry rubber content (DRC) of this rubber was 30%. The water to rubber ratios of 100:0, 90:10, 85:15, 80:20, 75:25, and 70:30 by weight of water were used in this study.

The laboratory evaluation program on lateritic soil/natural rubber latex blends included modified Proctor compaction, unconfined compressive strength (UCS) and cyclic wetting and drying test were undertaken in this study.

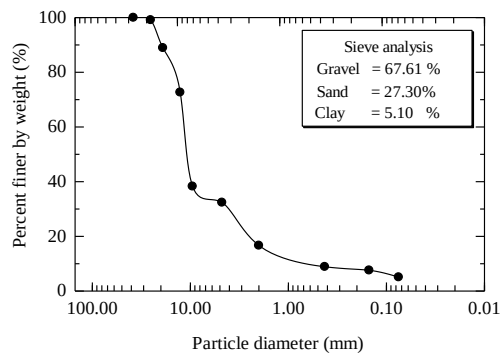


Figure 1. Grain size distribution of lateritic soil

Table 1. Basic properties of lateritic soil

Type of properties	value
Specific Gravity	2.78
Liquid limit	21%
Plastic limit	7.5%
Plastic Index	13.5%
Sieve analysis (USCS)	GW-GC
Gravel	67.61%
Sand	27.30%
Clay	5.10%

Modified compaction effort was used to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the lateritic soil/natural rubber latex blends. The modified compaction tests were conducted by following the ASTM D1557-12e1 (2012). The UCS samples were prepared at the OMC and MDD. The UCS samples had a diameter to height ratio of approximately 1.0 which is specified by the specification of Department of Highways and Department of Rural Roads, Thailand. The test was carried out in according with ASTM D1633 (2017).

The method of wetting and drying cycles test was carried out on cylindrical samples with 102 mm in diameter and 116.43 mm in height in accordance with ASTM D559-03 (2003). The samples were wrapped in vinyl bags and stored in a humidity-controlled room of constant temperature until 7 days of curing before wetting and drying test. The samples were submerged in deionized water at room temperature for 4 h. The samples were then dried in the oven at a temperature of 70°C for 12 h and air-dried at room temperature for at least 3 h. This process is referred to as 1 w-d cycle. The mass determination of the samples was carried out by weighing the samples at the end of each w-d cycle

compared with the initial weight of samples before w-d tests. After attaining the target w-d cycles (0, 3, and 6 w-d cycles), the samples were immersed in deionized water for 2 h at the constant temperature of $25 \pm 2^\circ\text{C}$ prior to UCS test. UCS and weight loss were then measured. The UCS tests were then undertaken with a rate of vertical displacement of 1 mm/min.

Results and Discussions

Figure 2 shows the modified compaction test results of the 3% cement content stabilized soil/natural rubber latex blends at various water/rubber ratios compared to the sample without natural rubber latex. All compaction curves of cement stabilized soil/natural rubber latex blends exhibit bell-shaped compaction pattern, which is a typical shape of compacted traditional geo-materials. The MDD of specimen increases as natural rubber latex replacement content increases until 20% then subsequently decreases as increasing natural rubber latex replacement content beyond 20%, while the OMC were similar despite the variations in the natural rubber latex contents. The higher MDD could be attributed to the increase in the lubrication effect from natural rubber latex.

Stress-strain relationship obtained from UCS test for all specimens are summarized in Figure 3. For 7-days curing period, the mean UCS value obtained was between 2,315 and 2,722 kPa for the cement stabilized soil/natural rubber latex blends. The incremental replacement ratio of natural rubber latex into soil cement is the cause of an increase in the strain at failure point for all samples. In this study, the toughness is defined as the required energy to deform the sample to a strain level equivalent to the peak stress and is calculated from the area under the stress-strain curve up to the selected strain value. As a result, the combination of cement and natural rubber latex shows a larger area, which demonstrates more ductile behavior of the sample when compared to the sample without natural rubber latex.

The relationship between the average 7-days UCS values of different mixtures with various rubber replacement are presented in Figure 4. UCS values of all specimens were found to meet the minimum 7-day UCS of 1,750 kPa for subbase materials specified by DOH, Thailand. The UCS values of the mixtures increase with increasing the natural rubber latex replacement. However, the reduction of UCS was found when increasing natural rubber latex replacement content beyond 20%. The UCS improvement could be attributed to the increase in the lubrication effect of soil particles

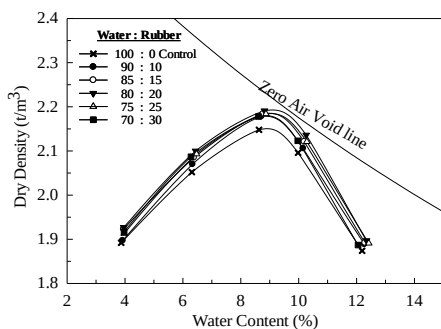


Figure 2. Compaction curves of 3% cement stabilized soil/natural rubber latex blends

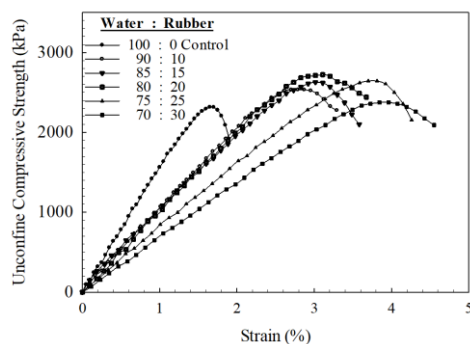


Figure 3. UCS Stress-strain behavior of 7 day soil/natural rubber latex blends

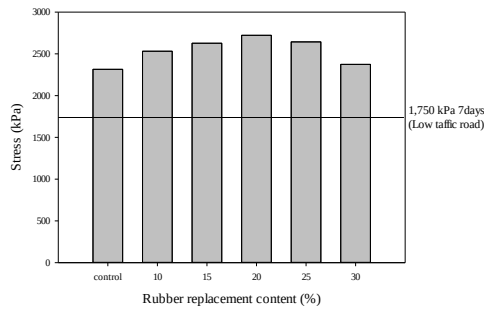


Figure 4. UCS results of cement stabilized soil/natural rubber latex blends

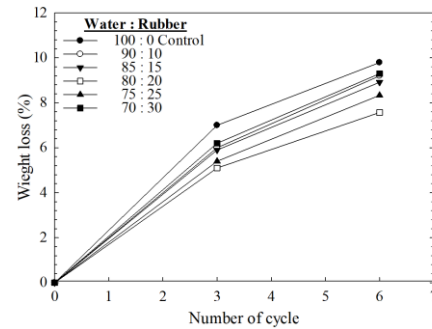


Figure 6. Relationship between weight loss and cycle number of cement stabilized soil/natural rubber latex blends

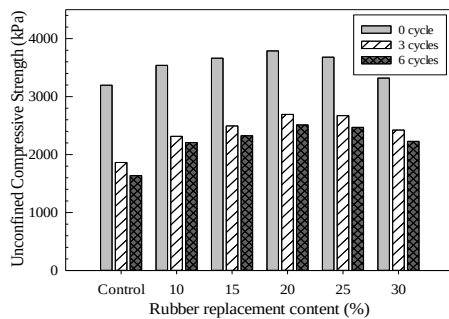


Figure 5. Relationship between UCS and w-d cycles of cement stabilized soil/natural rubber latex blends



Figure 7. Comparison of 0% and 20% rubber replacement ratio

with necessarily forming strong bonds between the rubber and soil particles. While the excessive increase in natural rubber latex (>20%), the rubber retarded the hydration reaction and led to reduce UCS (Yaowarat *et al.*, 2018; 2019).

Figure 5 shows the UCS of cement stabilized soil/natural rubber latex blends at various number of w-d cycles. The accumulation of w-d cycles lead to the reduction of UCS. At particular rubber replacement content, UCS decreases as number of w-d cycles increases. However, the loss in UCS at a particular w-d cycle was found to decrease as the rubber replacement increases. The deterioration in strength as increases is similar to previous research (Levy *et al.*, 1991). The weight loss of specimen versus the number of w-d cycles is shown in Figure 6. The cement stabilized soil with 20% rubber replacement ratio has a minimum weight loss when compared to the other mixture.

This indicates that the natural rubber latex entwines the soil particles and fills up some voids between soil particles which increase the attachment ability and ductility to the specimens (Buritatan *et al.*, 2020). Therefore, the soil matrix is more difficult separation during the w-d cycles test as

seen in Figure 7 and causes the percentage of weight loss is lowest than the other mixtures.

Conclusion

This research evaluates the effect of cement stabilized soil with natural rubber latex on density, UCS and durability against w-d cycles. The natural rubber latex is a polymer material, which can be used as a binder material to improve strength and durability. The following conclusions can be drawn from this research study.

1. The rubber latex can lubricate the soil compaction and fill the voids in the mixtures effectively. As a result, the MDD of the mixtures increases with increasing rubber content.

2. The UCS increases due to the density increased. The rubber in soil matrices makes the confinement to each soil particles, the addition of rubber in the specimen makes more attachment ability and hence, more ductile behavior.

3. The addition of rubber increases attachment ability causes the soil difficult to separate from the matrices. With this reason, the weight loss during

w-d cycles test is reduced and then the UCS for each w-d cycle slightly increase than sample without natural rubber.

Acknowledgments

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