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Application of Soil Stabilization Technique for Shoulder Construction in Sri Lanka

스리랑카 길어깨 적용을 위한 안정처리 재료의 적용성 평가 연구

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ABSTRACT

PURPOSES : The objective of this study is to evaluate the application of soil stabilization method for soft shoulder construction in the iRoad Project of Sri Lanka.

METHODS : Firstly, the quantitative analysis of soil strength improvement due to soil stabilization was done for soil samples collected from iRoad construction sites. Two types of soils were selected from iRoad Project sites and prepared for soil stabilization testing by the Road Development Authority. Secondly, the appropriate stabilizer was selected at given soil type based on test results. Two different stabilizers, ST-1 and ST-2, produced in Korea were used for estimating soil strength improvements. Finally, the optimum stabilizer content was determined for improving shoulder performance. The uniaxial compressive strength (UCS) test was conducted to evaluate the strength of stabilized soil samples in accordance with ASTM D 1633. The use of bottom ash as a stabilizer produced from power plant in Sri Lanka was also reviewed in this task.

RESULTS : It is found from the UCS testing that a 3% use of soil stabilizer can improve the strength up to 2~5 times in stabilized soft shoulder soils with respect to unstabilized soils. It is also observed from UCS testing that the ST-1 shows high strength improvement in 3% of stabilizer content but the strength improvement rate with increase of stabilizer content is relatively low compared with ST-2. The ST-2 shows a low UCS value at 3% of content but the UCS values increase significantly with increase of stabilizer content. When using the ST-2 as stabilizing agent, the 5% is recommended as minimum content based on UCS testing results. Based on the testing results for bottom ash replacement, the stabilized sample with bottom ash shows the low strength value.

CONCLUSIONS : This paper is intended to check the feasibility for use the soil stabilization technique for shoulder construction in Sri Lanka. The use of soil stabilizer enables to improve the durability and strength in soft shoulder materials. When applying the bottom ash as a soil stabilizer, various testings should be conducted to satisfy the specification criteria.

Keywords
Soil Stabilization, Soft Shoulder, Uniaxial Compressive Strength, Bottom Ash

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1. INTRODUCTION

The Government of Sri Lanka is implementing the Integrated Road Investment Program (iRoad) funded by Asian Development Bank (ADB) to improve the connectivity between rural communities and socioeconomic centers by improving the transport efficiency on selected national, provincial and local roads. Under the iRoad Program, around 3000km of rural roads in Southern, Sabaragamuwa, Central, North Central, North Western Provinces and Kalutara district in Western province will be improved/rehabilitated and maintained for three years through 42 civil works contracts (iRoad, 2017).

In Sri Lanka, the shoulder construction in asphalt pavements has been done using the materials transported from borrow pit in the iRoad Project due to the lack of quality of in-situ soils. After excavating 150~200mm thick and 500mm wide shoulder area, borrow pit materials are placed and compacted according to specifications. And then, the excavated in-situ soils are transported and dumped in designated location.

It is estimated that this process of shoulder construction is not economical due to high material transportation cost and can also induce the environmental issues by disposal of in-situ soils. It can also cause distresses such as surface rutting and edge drop-off in soft shoulder section due to bearing capacity failure and off-tracking of vehicle. The heavy rainfall in Sri Lanka can induce severe erosion problem when using the soft shoulder.

To improve the strength and durability of pavement shoulders in the iRoad Project, the soil stabilization will be a good alternative to solve the above mentioned problems. The use of in-situ soils with addition of soil stabilizer enables to reduce the construction cost of shoulder section and mitigate the environment issues.

The objective of this study is to review the application of soil stabilization method on shoulder construction in the iRoad Project. Firstly, the quantitative analysis of soil strength improvement due to soil stabilization was done for soil samples collected from iRoad construction site. Secondly, the appropriate stabilizer was selected at given soil type based on test results. Finally, the optimum stabilizer content was determined for improving shoulder performance. The use of bottom ash as a stabilizer produced from power plant in Sri Lanka was also reviewed in this task.

2. EROSION PROBLEMS in SOFT SHOULDER

In iRoad Project, the shoulder of pavement section is generally constructed by soft shoulder method after construction of main line because of low volume traffic. After laying down the final layer of asphalt, carriageway was cut almost vertically on the edges. It is then backfilled with the borrow pit soils and leveled with a small roller.

The early disappearance of the topsoil causes a deviation in the main line and the shoulder. Therefore, it is necessary to improve the overall construction method, and to use the soil stabilizing material and post-construction quality control techniques.

Since the most of roads in Sri Lanka is constructed as one lane in each direction, the off-tracking of vehicle can cause the loss of top soil in the soft shoulder (Fig. 1). The average annual precipitation in rainy season is more than 3,500 mm in this region. A large amount of heavy rainfall can accelerate the degree of erosion in shoulder section (Fig. 2). An insufficient compaction effort due to the small roller compactor can also induce the erosion problem.

Fig. 1 Soft Shoulder Erosion in Kandy

Fig. 2 Soft Shoulder Erosion at Mile Road in Bandarawela

3. SOIL STABILIZATION TECHNIQUES

Soil stabilization is defined as the physical, chemical, biological, or combined method of changing a natural soil to meet an engineering purpose. This technique enables to increase bearing capabilities and performance of in-situ soils, sands, and other waste materials in order to strengthen roads. The followings are the goals of soil stabilization techniques (TxDOT 2005);

- Increase strength to provide long-term support for the pavement structure
- Reduce shrink/swell of expansive soils or existing materials
- Reduce pavement thickness
- Reduce moisture susceptibility
- Utilize local materials
- Bind salvaged materials used on pavement rehabilitation projects

Mechanisms of soil stabilization technique can be classified as coating soil particles, binding soil particles, and formation of new compounds. The stabilizing additives widely used are asphalt, cement, lime, and fly ash. The asphalt is visco-elastic material that coats and binds aggregate and soil particles together. This coating and binding mechanism can increase the strength and stiffness and reduce the moisture susceptibility. The use of cement is the formation mechanism of new compounds by hydration process (Bhattacharja and Bhatty 2003). It enables to increase in strength and moisture resistance by chemical reaction between calcium hydroxide and the soluble silica and alumina in soils. When lime is combined with water and the soluble silica and alumina present in clay, a chemical reaction occurs. This reaction alters the particle structure and increase the resistance to shrink-swell and moisture susceptibility. It also binds the soil particles and gain the strength. When fly ash, by-product of coal combustion, is combined with water, a cementitious reaction occurs to bind the soil particles. It is capable of increase the resistance to shrink-swell phenomena and moisture susceptibility. The reaction rate is generally slower than cement but more rapidly than lime. The advantages of ash products in soil stabilization are to improve the workability and durability, reduce the hydration heat, improve the long term strength, and good water tightness. Several researches have been conducted to investigate the performance of stabilization technique in shoulder section (Mekkawy et al., 2010).

In Sri Lanka, there are various types of soil in construction sites located at different regions after reviewing the soil property database in the iRoad project. It is well known that soil type in the field is the major factor to select the appropriate stabilizer type and determine the quantity of stabilizer in mix design. The procedure to determine the soil stabilization additive and construction method should be established for different field condition. The following figure shows the typical application range of stabilization techniques.

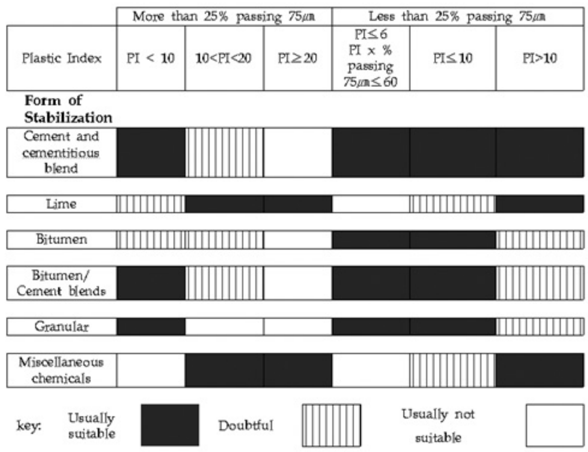

Fig. 3 Application Range of Stabilization Techniques (TxDOT 2005)

4. SOIL SAMPLE & SOIL STABILIZER

Two types of in-situ soils were collected from iRoad Project sites and prepared for soil stabilization testing by the Road Development Authority (RDA) in Sri Lanka. The following Table 1 shows the basic soil properties and California Bearing Ratio (CBR) tested by the RDA. The soil samples are sandy soils and the optimum moisture content for these soil samples range from 9 to 10%. It is found from this table that Soil B show two times higher CBR value than Soil A.

Table 1. Basis Soil Properties

Soil type	Optimum moisture content(%)	Maximum dry density (g/cm^3)	CBR (%)	Soil classification
A	9.1	1.99	14	SM(Inorganic)
B	9.8	2.12	27	SC

Two different soil stabilizers manufactured in Korea were used to improve the strength and durability of soft shoulder soils in Sri Lanka. The ST-1 is the eco-friendly stabilizing additives and good for high plastic or organic soils. It is capable of increasing strength by forming ettringite crystals through chemical solidification and improving the long term strength by pozzolan reaction. The ST-2 is the high functional solidifier by utilizing ashes and carbonized materials. It can solidify the soil quickly with hydration products bridging between the soil particles.

5. SAMPLE PREPARATION

Two different stabilizers, ST-1 and ST-2 produced in Korea were used for estimating soil strength improvements. These soil stabilizers were mixed in 3, 5, and 7% weight ratios with soils A and B. The unstabilized soil samples were also prepared for comparison purposes and reference data. In order to evaluate the possible use of bottom ash as a stabilizer, a 30% of ST-1 and ST-2 was substituted with bottom ash. The bottom ash less than 0.075mm in size was obtained from the power plant in Sri Lanka.

The mixing moisture content was determined as 10~11% since the optimum moisture contents of each natural soils are 9.1 and 9.8% and addition of stabilizer requires for 1 or 2 percent more water content. Samples for testing were fabricated using 100 mm diameter and 200 mm height of cylinder molds using gyratory compactor. A pressure of 600 kPa was applied on specimens with 50 repetitions for achieving the target density. The height and weight were measured to calculate the volume of compacted samples. The UCS testing samples were prepared from May 15 to 17, 2017 in R&D Center of RDA.

Table 2 presents the design parameters and samples numbers for compressive strength testing. A total of 62 samples were prepared for the UCS testing in this task.

Table 2. Type of Soil Stabilizer and Content Used for Sampling

Stabilizer type	Soil type	Stabilizer content (%)	Curing time (Days)	Replicate	No. of samples
ST1, ST2	A, B	3, 5, 7	3 & 27	2	48
Unstabilized	A, B	-	-	3	6
Bottom ash	B	5, 7	3	2	8
Total	-	-	-	-	62

6. TEST METHOD

The uniaxial compressive strength (UCS) test was conducted to evaluate the strength of stabilized soil samples in accordance with ASTM D 1633. The UCS was determined by applying a load at 1mm/min rate until specimen failure. The UCS values were modified according to correction factor based on height/diameter ratio. This testing was conducted on stabilized samples after 3 and 28 days curing.

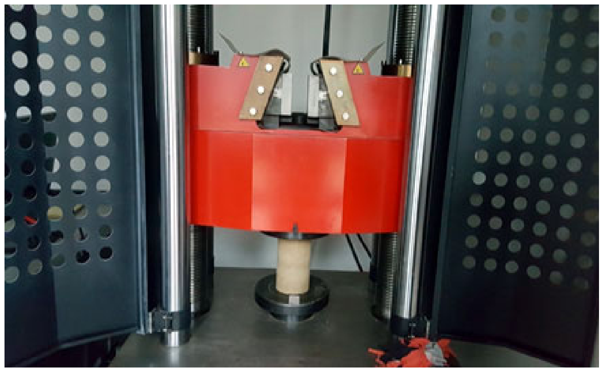

Fig. 4 Uniaxial Compression Testing Equipment

Fig. 5 Stabilized Soil Sample after Failure

7. TEST RESULTS

The UCS test results are summarized in this chapter for stabilized soil samples after 3 and 28 days curing . The Fig. 6 and 9 show the UCS values of samples stabilized with ST-1 and ST-2 at different stabilizer content for each soil type. It is noted that the UCS values of unstabilized soil A and B are 0.21 and 0.67 MPa, respectively. The CBR testing results conducted by RDA also indicate that the Soil B (27) has higher CBR value than Soil A (14).

It was found from Fig. 6 and 7 that only 3% use of stabilizer can improve the strength up to 5 times for soil A and 2 time for Soil B with respect to unstabilized soils. It is also observed from these figures that the UCS values tend to increase as the stabilizer content increases. The Road Note 31 suggests the minimum UCS value for roadbase stabilization as 1.5 MPa TRL 1993. Except for 3% of ST-2, the UCS values of all the stabilized samples satisfy with the specification criteria.

The ST-1 shows high strength improvement in 3% of stabilizer content but the strength improvement rate with increase of stabilizer content is relatively low compared with ST-2. The ST-2 shows a low UCS value at 3% of content but the UCS values increase significantly with increase of stabilizer content. When using the ST-2 as stabilizing agent, the 5% is recommended as minimum content based on UCS testing results.

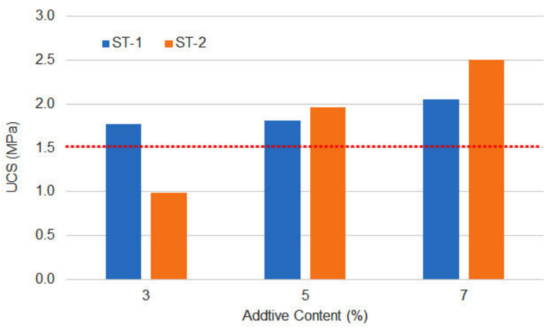

Fig. 6 UCS Values of Stabilized Samples for Soil A (3 days curing)

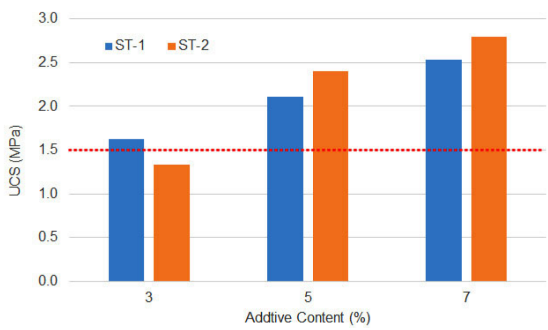

Fig. 7 UCS Values of Stabilized Samples for Soil B (3 days curing)

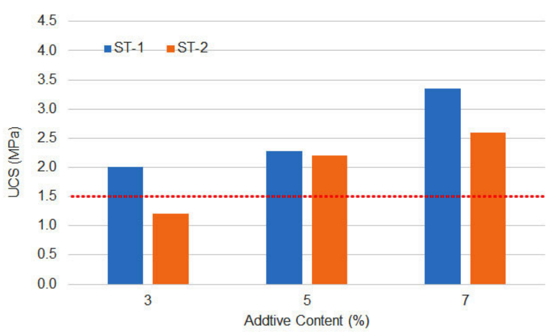

Fig. 8 UCS Values of Stabilized Samples for Soil A (28 days curing)

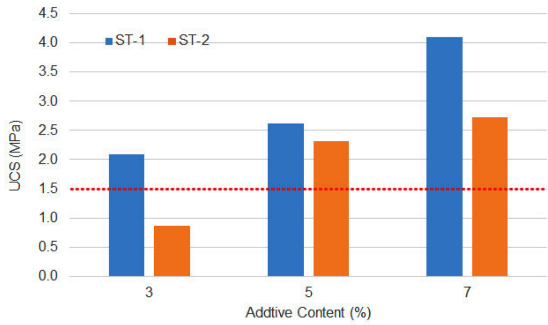

Fig. 9 UCS Values of Stabilized Samples for Soil B (28 days curing)

Fig. 10 presents the effect of bottom ash on UCS values of stabilized samples. A 30% of stabilizer was replaced by the bottom ash prepared by the RDA. When substituting the stabilizer with bottom ash produced in Sri Lanka, the UCS values of stabilized sample with bottom ash generally are lower than sample without bottom ash. The degree of reduction in strength due to use of bottom ash is higher for 28 days curing samples The reduction ratio of UCS values due to the application of bottom ash in ST-1 is lower than that in ST-2. Since our research tested only one sample for each case due to lack of natural soils, the additional testing will be necessary in near future.

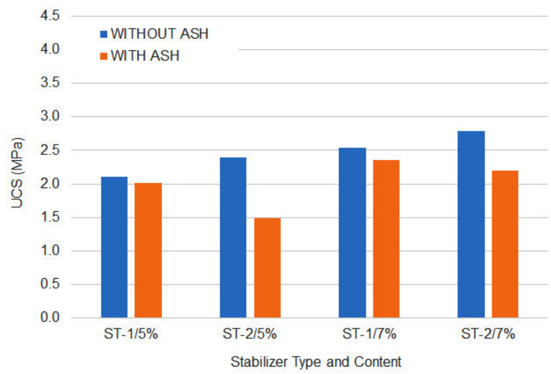

Fig. 10 Effect of Bottom Ash on UCS of Stabilized Samples (3 days curing)

8. CONCLUSIONS

The objective of this study is to review the application of soil stabilization method for soft shoulder construction in the iRoad Project of Sri Lanka. A 3% use of soil stabilizer can improve the strength up to 2~5 times in stabilized soft shoulder soils with respect to unstabilized soils. It is found from UCS testing that the ST-1 shows high strength improvement in 3% of stabilizer content but the strength improvement rate with increase of stabilizer content is relatively low compared with ST-2. The ST-2 shows a low UCS value at 3% of content but the UCS values increase significantly with increase of stabilizer content. When using the ST-2 as stabilizing agent, the 5% is recommended as minimum content based on UCS testing results. Based on the testing results for bottom ash replacement, the stabilized sample with bottom ash shows the low strength value. It is recommended to conduct an additional testing to assure the use of bottom ash as soil stabilizer in soft shoulder construction.

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