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EXTENDED ABSTRACT

Laboratory Evaluation of Stabilization of Clay Soil with Recycled Concrete Materials for Road Construction Layers

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1. Introduction

Expansive soils are considered as problematic soils due to their high swelling and shrinkage potential and low bearing capacity. Cracks are usually observed in the structures based on this type of soil, which causes the instability of the structure and large settlements in the structure. Due to the scarcity of land and the rapid progress of construction, engineers have focused on construction on such soils. These lands require soil stabilization with the help of various additives to improve the subgrade and the strength characteristics of weak soils.

Soil stabilization is a technique that is used to improve and treat soil engineering properties such as strength, stiffness and compressibility of the unfavorable soil in site. Subgrade improvement using mechanical and chemical techniques is very common in transportation infrastructure projects. Although natural materials are mainly used for mechanical stabilization of subgrade soil, there is limited past studies on the relationship with the use of RCA in subgrade soil stabilization.

In this research, the behavior of clay subgrade soil stabilized with recycled concrete aggregate (RCA) and granulated blast furnace slag (GBS) as a chemical stabilizer for use in rigid and flexible pavements has been evaluated. At first, proctor compaction, uniaxial compressive strength and California bearing ratio tests have been conducted on different combinations of clay, RCA and GBS in order to reach the optimum additive content. RCA and GBS additives have been used in order to achieve the target uniaxial strength (28-day minimum strength of 1379kPa and 1724kPa for rigid and flexible pavements, respectively) as suggested by UFC for stabilized subgrade layers.

2. Methodology

2.1. Experimental study

This research used laboratory tests to investigate the suitability of RCA for clay subgrade soil stabilization. The soil used in this research was taken from the western part of Zanjan city, Iran. The measured clay liquid limit was 65, and the plasticity index was 33. Based on the AASHTO classification system, the clay was classified as an A-7-5 soil, and according to the Unified Soil Classification System, it was high plasticity clay (CH). The C&D materials consisted of concrete waste and recycled concrete aggregate (RCA) are obtained from it. RCA waste obtained from the demolition of low-rise buildings in Zanjan city. The RCA waste is transferred to the transformation site and the large concrete pieces are crushed by the crusher. After completing the

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transformation process, concrete materials are obtained in the range of 0-6, 6-12, 12-19 and 19-25mm. The slag used in this research is the type of granulated blast furnace slag (GBS), which was extracted from Esfahan Steel Company, Iran. The grain size distribution for the used materials is shown in Fig. 1.

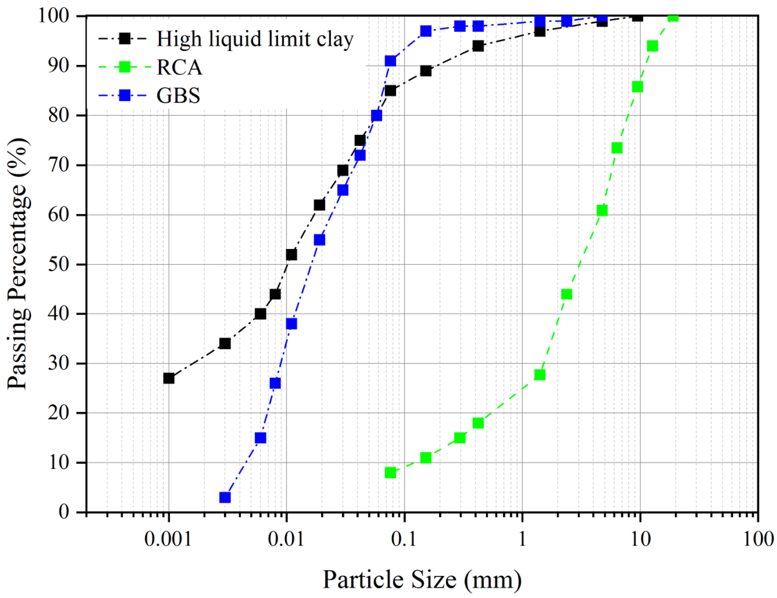

Fig. 1. Particle size distribution curves of the tested clay, RCA and GBS

2.2. Testing procedure

The standard Proctor test according to ASTM D698 is performed for different combinations in order to reach the optimum moisture content (OMC) and the maximum dry unit weight (MUW), which is required for the preparation of samples for uniaxial compressive Strength (UCS) and CBR tests. According to ASTM D2166, a standard UCS specimen is cylindrical with a diameter of 71mm and a height of 142mm (i.e., a 2:1 ratio) and the samples were compacted in 5 layers in order to reach the MUW and OMC. To investigate the effect of curing age on the stabilized samples, the samples should be maintained in a closed space carefully. Hence, the clay-RCA and clay-RCA-GBS mixtures were cured in a humid chamber (with a relative humidity of 80% to 90 % and temperature between 20° to 23°C) for 3, 7 and 28 days. CBR tests are also performed according to ASTM D1883 on different combination. The specimens were compacted to the MUW and OMC of untreated soil and stabilized clay-RCA mixtures with 0%, 3%, 6%, 9%, and 12% GBS contents in five layers in a mold with a diameter of 152.4mm and a height of 177.8mm. After the7-day moist cured samples were immersed in water for 96 hours, they are tested under a seating pressure of 4.5 kg and a penetration rate of 1.27mm/min. The results of stress versus penetration are used to determine the CBR value.

3. Results and discussion

Adding RCA to clay increases MDD and decreases OWC. When the percentage of RCA reaches 30, the MDD of the mixture increases from 1.65g/cm^3 to 1.80g/cm^3 and the OWC decreases from 22.50% to 13.7%. The decrease in OWC was probably the result of lower specific surface area of the RCA than that of the clay. The increases in MDD can be attributed to the intergranular porosity ratio concept. Also, for clay treated with RCA, the addition of GBS increases MDD and decreases OWC. The increase in MDD value with the addition of GBS can be due to the higher grain density (Gs) of GBS compared to clay soil and RCA. Also, the increase of GBS content decreases the OWC of clay-RCA mixture, which is because GBS materials required less water to reach the OWC.

The soaked CBR value increases from 2.9% for untreated clay to 10.3% for stabilized clay with 30% RCA. Also, the addition of RCA to clay improved the mixture stiffness. Adding RCA create a two-phase composite consisting of hard particles in a soft matrix with overall improved composite stiffness. The increase in CBR value due to the addition of RCA aggregates may be attributed to the improved strength in clay-RCA mixtures due to improved strain compatibility between RCA particle and clay matrix.

The results of UCS and failure strain for clay-RCA mixture with different content of RCA at different curing times (3-7 and 28-days) are shown in Fig. 2. As can be seen in the figure, for all curing times, as the content of

RCA increases, the value of UCS increases up to RCA=20% and then decreases. Also, the failure strain decreases with increasing RCA content. However, the amount of increase in UCS was not enough to reach the target uniaxial strength proposed by UFC (28 days UCS value of 1379kPa and 1724kPa for rigid and flexible pavements, respectively) for stabilized subgrade/subbase layers. As a result, an additional stabilizer, such as granulated blast furnace slag (GBS), was selected to achieve the target value.

Clay soil with an optimum value of RCA=20% was used as a base study the effect of GBS different content and curing time on UCS value. UCS tests were conducted at different percentages of GBS in different curing times (3-7 and 28-days curing age) in order to determine the required content in order to reach the 28-day strength target value suggested by UFC. However, adding RCA caused considerable improvement in the UCS value of mixtures. As seen in Fig. 3, for stabilized clay with 20% RCA, UCS increased with increasing GBS content. The GBS consists of calcium-silicates; hydration of GBS occurs to form cementitious gels of hydrated calcium silicates and calcium hydroxide. Cementitious gels strengthen and bind the bonds between clay-RCA mixtures and form a hardened skeleton matrix. The results showed a slight decrease in UCS values for clay-RCA mixtures stabilized with 12% GBS compared with mixtures stabilized with 9% GBS. The drop in UCS value may have been due to drying-induced microcracking and excess amounts of GBS will behave as low-strength filler that weakens the clay–RCA mixture

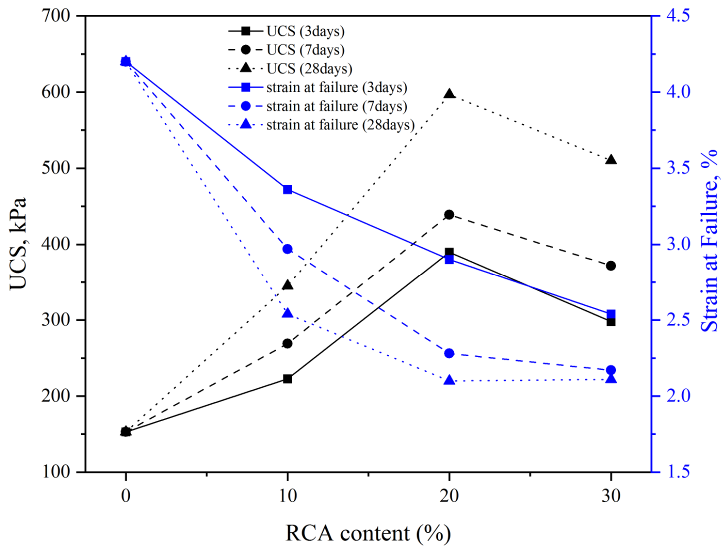

Fig. 2. UCS and strain at failure for soils with different percentages of RCA

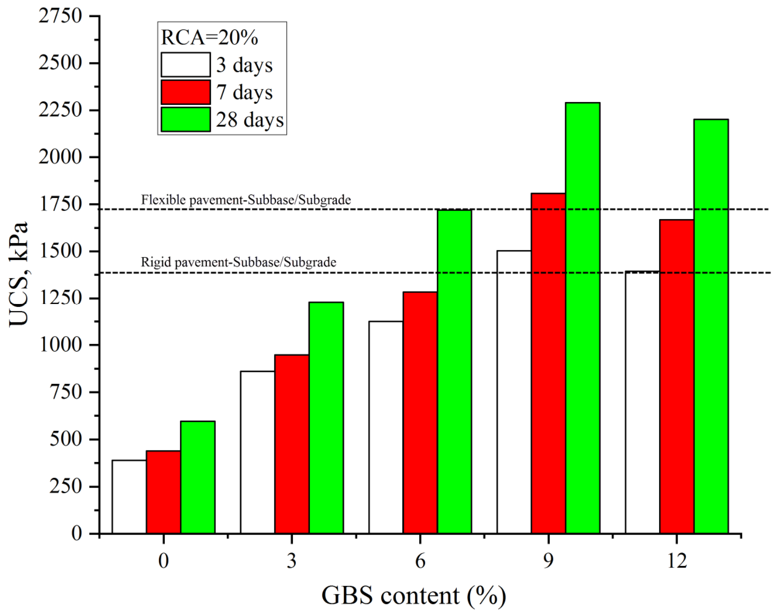

Fig. 3. UCS of clay-20%RCA mixture with GBS different content at different curing times, and limits of UFC for subgrade stabilization

4. Conclusions

The main purpose of this study is to use construction and demolition (C&D) wastes to improve the strength of clay subgrade, and GBS chemical stabilizer has been used to achieve this aim as best as possible. The obtained results showed that as RCA content increased, UCS values increased for clay subgrade with up to 20% RCA content and decreased after that. The use of GBS additive significantly improved the mechanical properties of subgrade soil, transforming it into an appropriate subgrade material. Significant increases in UCS and CBR were found in clay-20%RCA mixture stabilized with GBS.