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EXTENDED ABSTRACT

Laboratory Study of the Effect of Age, Temperature, and Fiber Content on the Behavior of Environmentally Friendly Reinforced Lime-Cement Concrete (RLCC)

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Reinforced Lime-Cement-Concrete (RLCC), Curing age, Recycled Tire Polymer Fibers (RTPF), Uniaxial Compressive Strength (UCS), Modulus of elasticity.

1. Introduction

Current research has tried to study the effects of curing ages, curing temperature and Recycled Tire Polymer Fibers (RTPF) content on geotechnical properties of RLCC, such as unconfined compressive strength (UCS), secant modulus (Es), strain frailure (ε_f) and deformability index (I_d). The UCS test is a criterion to estimate the geotechnical parameters of RLCC samples in the presented research.

2. Methodology, sample preparation and testing

2.1. Methodology

In this study, cylindrical soil, Lime Concrete (LCC) and RLCC specimens were prepared with different fiber contents and cured in different curing conditions and periods.

Table **1** shows the name, curing times, and curing conditions for all specimens. However, following the mix design used in a recent research conducted by the authors on LCC (Jahandari et. al., 2019), the percentages of cement and lime in all specimens were kept constant at 4% and 3% of the dry weight of clayey soil, respectively. The water content was 24% of the total dry weight of the soil, cement, and lime in the mixture. The fibers were added to the mixes at 0%, 0.4%, 1%, 1.7% and 2.5% of the total dry weight of clayey soil, cement, and lime mixture.

2.2. Sample preparation

In order to prepare the specimens, clay soil and fibers were properly mixed together. The lime-cement slurry was made by mixing lime and cement with water content that amount of them is indicated in Table1. Then, the lime-cement slurry was added to the mixture of soil and fibers. The process of mixing was continued by an automatic mixer for 3 minutes until a homogeneous material was attained. The fresh mixture was poured into cylindrical molds with a diameter of 60 mm and a height of 120 mm. It should be noted that because of adopting a relatively high workability to represent the typical condition of RLCC and LCC in the real projects, the mixture could be properly placed in the molds without any vibration or compaction.

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Table 1. Name and specification of the specimens.

Specimen	Lime (%)	Cement (%)	Water (%)	Fiber (%)	Curing temp. (ºC)		Number of specimens
					30	60	
					Curing time (days)		
Soil (control 1)	0	0	24	0	14	3	2x3
LC	3	0	24	0	28, 14	-	2x3
CC	0	4	24	0	28, 14	-	2x3
LCC (control 2)	3	4	24	0	28, 14	21, 3	4x3
RLCC 0.4	3	4	24	0.4	28, 14	21, 3	4x3
RLCC 1.0	3	4	24	1.0	28, 14	21, 3	4x3
RLCC 1.7	3	4	24	1.7	28, 14	21, 3	4x3
RLCC 2.5	3	4	24	2.5	28, 14	21, 3	4x3

2.3. Testing

Three replicate specimens were prepared for each mix design, curing conditions and periods to ensure the accuracy of the test results. After 72 hours of RLCC casting, the specimens were demolded and then placed in a plastic bags to avoid significant variations in the moisture. Half of the samples were cured for 3 or 21 days at a temperature of 60 °C in oven, and the rest were cured for 14 or 28 days in oven at a temperature of 30 °C. After curing, the uniaxial compression tests with the loading rate of 1 mm/min were carried out on the samples. Three tests were conducted for each condition, and the average values were calculated and reported.

3. Results and discussion

3.1. Failure pattern

Fig. 1 shows the failure patterns of the control 2 and RLCC samples. The LCC without fibers had diagonal cracks and gradually expanded towards the middle of the sample. Therefore, the LCC surface clod spalled off, leading to a vivid brittle failure. For RLCC samples with 0.4% or 1.7% fibers, the crack width became much smaller with increasing fiber content. The uniformly dispersed fibers in RLCC created mesh constraint on soil particles. Thus, the crack initiation and development were inhibited. By adding extra fibers (2.5%) to the RLCC, the fibers agglomerated in the RLCC. The reason was due to developing cracks in RLCC and destroying the RLCC gradually from the fiber agglomeration that the frictional resistance between fibers is smaller as compared with that between fiber and soil particle. (Duan and Zhang, 2019) also reported a similar failure pattern.

Fig. 1. A view of typical specimens after failure (cured at 60°C)

3.2. Unconfined compressive strength (UCS) and stress-strain behavior of LCC specimens

The results show that the samples cured in oven at 60°C had higher UCS values compared with samples cured at 30°C, which is because hydration enhances in cementitious materials cured at elevated temperatures compared to samples cured at lower temperature. Further, at any curing time and curing condition, by increasing the fiber content, the secant modulus decreased because the contact behaviors between cement and soil particles was decreased by adding fiber

4. Conclusions

It has recently been proved that LCC has a superior performance over Lime Concrete (LC) in the presence of moisture resulted from capillary action and groundwater level increment under the foundations. However, because LCC is often used under the foundation of buildings, the uneven settlement of soil underneath usually causes cracks and subsequent durability issues in the concrete, more specifically in the presence of moisture and groundwater. The current research resolved this problem by incorporating small amounts of a very low-cost fiber in the LCC mix design to act as bridging ligaments behind crack tips to resist crack and improve the ductility. The performance of RLCC has been studied by focusing on the effects of various fiber contents, curing periods, and curing conditions on a number of geotechnical properties including the compressive strength, stress-strain behavior, secant modulus, deformability index and failure strain. The following main conclusions are drawn:

- In all curing periods and conditions, the ductility of RLCC significantly increases with the addition of Recycled Tire Polymer Fibers (RTPF). For example, deformability index of RLCC with adding fibers to the mix design increases between 50 to 100% compared with the reference LCC sample. In addition, RLCC with higher fiber content shows more ductile post-peak behavior compared to LCC or RLCC with lower fiber content .
- Curing time and curing condition significantly affect the geotechnical properties of LCC specimens. For example, the specimens cured for 3 days in 60°C show significantly higher UCS values compared with the specimens cured at 30°C for 14 and 28 days, and the UCS of specimens cured in 60°C for 21 days is almost 1.6 times higher than those cured for 28 days at 30°C. These results show that it is reasonable to cure the LCC samples in high temperature (60°C) for one or two days (instead of 28 days in 30°C) in order to save time in real LCC and RLCC projects.
- The secant modulus of specimens for any curing condition and curing period decrease by increasing the fiber content. Moreover, the deformability index of specimens for any curing condition and curing period increases by increasing the fiber content.

5. References

Duan XL, Zhang JS, "Mechanical properties, failure mode, and microstructure of soil-cement modified with fly ash and polypropylene fiber", Advances in Materials Science and Engineering, 2019.

Jahandari S, Saberian M, Tao Z, Mojtahedi SF, Li J, Ghasemi M, Rezvani SS, Li W, "Effects of saturation degrees, freezing-thawing, and curing on geotechnical properties of lime and lime-cement concretes", Cold Regions Science and Technology, 2019, 160, 242-251.