

Stabilized Kaolinite with -Strength Behavior of Cement Polypropylene Fibers under Water and –Polyester Sodium Chloride Immersion

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ABSTRACT

grained soils. This -stabilized fine-Environmental exposure can adversely affect the mechanical performance of cement study investigates the effects of cement content and a fixed 1% polypropylene–by dry weight polyester (PP–PES) fiber blend on the unconfined compressive strength(UCS)and strength retention of kaolinitic soil stabilized with Type II Portland cement. Cement contents of 0%, 1/5% , 2/5% and 4% were considered, with and without 1% PP –PES fibers. The total fiber content consisted of 0.5% polyester and 0/5% polypropylene, with nominal lengths of 12 and 3 mm, respectively. The specimens were cured for 28 days and then evaluated under a dry reference condition, water immersion, and immersion in a-distilled 1% sodium chloride (NaCl)solution. The UCS was determined according to ASTM D2166, and the strength retention factor (SRF)of exposed UCS to dry was calculated as the ratio way analysis of variance-UCS. One(ANOVA)and Tukey HSD tests were used to evaluate the statistical differences among the mixtures. Under dry conditions, increasing the cement content from 1/5% to 4% increased the UCS of specimens from free-fiber 0/96 to 2/43MPa, corresponding to an increase of approximately 153% At . 4% cement, the addition of 1% PP increased the dry UCS from–PES 2/43 to 2/80 MPa. After immersion, the mixture containing 4% cement and 1% the highest exposed UCS, reaching PP exhibited–PES 1/49 MPa in distilled water and 1/36 MPa in the NaCl solution. Its corresponding SRFs were 53/2% and 48/6% free -respectively. Compared with the fiber mixture at4% PP increased SRF by–cement, the addition of PES 38/1 and 40/0 percentage points in distilled water PP fiber –and saline solution, respectively. The results demonstrate that the combined use of cement and a fixed PES content can improve both initial strength and strength retention under the investigated exposure conditions.

KEYWORDS

Kaolinite, sodium chloride,polyester fibers ,polypropylene fibers ,Portland cement

1. Introduction

Fine-grained soils often exhibit low strength and sensitivity to environmental conditions. Cement stabilization can improve their mechanical performance through cementitious bonding, while discrete fibers can provide additional tensile resistance and limit localized deformation [1_3]. However, strength retention may vary with soil type, stabilizer content, fiber characteristics, and exposure environment [3_6].

Limited studies have examined a fixed combined polyester–polypropylene (PES–PP) fiber content at different cement contents while comparing water and saline exposure in kaolinitic soil. Therefore, this study evaluates 0%, 1.5%, 2.5%, and 4% cement combined with a constant 1% PES–PP fiber blend. Specimens were cured for 28 days and tested under dry, distilled-water, and 1% NaCl exposure conditions. The main contribution is the systematic evaluation of cement content at a fixed fiber content under identical preparation and curing conditions.

2. Methodology

Kaolinitic soil from Zenoz, Tabriz, containing approximately 70% kaolinite, was used. The soil had a liquid limit of 39%, plasticity index of 21%, specific gravity of 2.67, maximum dry density of 1561 kg/m³, and optimum moisture content of 19%, and was classified as CL. Type II Portland cement was used at 0%, 1.5%, 2.5%, and 4% of dry soil mass.

The fiber-reinforced mixtures contained 1% total PES–PP fibers, consisting of 0.5% polyester with a nominal length of 12 mm and 0.5% polypropylene with a nominal length of 3 mm. Eight mixtures were prepared, including fiber-free and fiber-reinforced mixtures at the investigated cement contents. Specimens were statically compacted in 38 × 76 mm cylindrical molds and cured for 28 days.

After curing, specimens were evaluated under dry, distilled-water, and 1% NaCl conditions. Exposed specimens underwent 32 h of immersion followed by 1 h at 110 °C and cooling to room temperature; this represented one exposure stage. UCS was determined according to ASTM D2166 at 1 mm/min using three specimens per condition. The strength retention factor (SRF) was calculated as:

(1)

Mean UCS, standard deviation, standard error, and coefficient of variation were determined. One-way ANOVA, Tukey HSD, and eta squared (η^2) were used to evaluate statistical significance and effect size at a 95% confidence level.

3. Results and Discussion

Under dry conditions, increasing cement content from 1.5% to 4% increased the UCS of fiber-free mixtures from 0.96 to 2.43 MPa, corresponding to an approximately 153% increase. Adding 1% PES–PP further increased UCS from 0.96 to 1.84 MPa at 1.5% cement, from 2.11 to 2.65 MPa at 2.5% cement, and from 2.43 to 2.80 MPa at 4% cement. Thus, the highest dry UCS was obtained with 4% cement and 1% PES–PP.

Environmental exposure substantially reduced UCS. As shown in Figure 1, the 4% cement + 1% PES–PP mixture retained the highest exposed strength, with UCS values of 1.49 MPa in distilled water and 1.36 MPa in 1% NaCl, compared with 2.80 MPa under dry conditions.

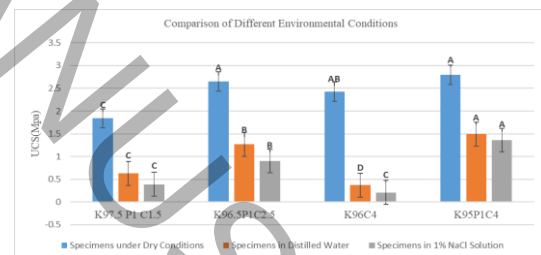


Fig 1. Stability and Durability of the Selected Specimens in Different Environments

For the same mixture, the SRFs were 53.2% in distilled water and 48.6% in NaCl. In comparison, the fiber-free 4% cement mixture showed SRFs of only 15.1% and 8.6%, respectively. Therefore, adding 1% PES–PP increased SRF by 38.1 percentage points in distilled water and 40.0 percentage points in the saline solution.

The lower cement mixtures also showed measurable strength after exposure. For K97.5P1C1.5, UCS values

were 0.63 and 0.39 MPa in distilled water and NaCl, respectively, while K96.5P1C2.5 reached 1.27 and 0.90 MPa. Overall, saline exposure generally produced lower strength than distilled water among the mixtures with measurable results.

ANOVA confirmed a significant effect of mixture composition on UCS under all conditions. The values were $F = 141.24$, $p < 0.001$, $\eta^2 = 0.984$ for dry conditions; $F = 208.35$, $p < 0.001$, $\eta^2 = 0.987$ for distilled water; and $F = 152.99$, $p < 0.001$, $\eta^2 = 0.983$ for NaCl. These results demonstrate the substantial influence of cement content and fiber reinforcement on both initial strength and strength retention

4. Conclusions

The results show that increasing cement content substantially improved the dry UCS of kaolinitic soil. The fixed 1% PES-PP fiber blend further enhanced UCS at all investigated cement contents, with the highest value of 2.80 MPa obtained at 4% cement. Environmental exposure reduced strength, but fiber-reinforced mixtures retained considerably more strength than their fiber-free counterparts. At 4% cement, PES-PP increased SRF by 38.1 and 40.0 percentage points in distilled water and NaCl, respectively. Overall, the combination of 4% cement and 1% PES-PP provided the best strength and strength retention under the investigated conditions.

5. References

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