# Performance of fiber and industrial wastes in enhancing soil stabilization process compared to cement

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**ABSTRACT**

**In the present study, the effectiveness of a new combination of industrial wastes including calcium carbide residue (CCR) and silica-fume (SF) along with polypropylene fiber was investigated in comparison with cement for improving soft clays and increasing their durability. The results showed that in the normal curing condition, the use of CCR alone has a little effect on the soil geo-mechanical performance. On the other hand, despite the initial favorable performance of cement, but the W-D cycle with the failure of cement nanostructures can lead to the disturbance and even complete loss of the soil bearing capacity. On the contrast, the combination of CCR with SF had a prominent role on the stabilization process and a much lower deterioration potential was observed in the presence of the optimal ratio of CCR-SF. According to SEM-EDX and XRD analysis, expansion of solidification and reduction of voids were evaluated as the main factors of the more appropriate response of the recent system. Adding fiber to this series of samples had a significant effect on the growth of tensile strength, better absorption of energy, reduction of cracking ability and, as a result, improving the stability of soil matrix. Following such a condition, the strength of reinforced sample containing 15% additive was found to be about 1.8 times the threshold allowed for successful stabilization. This can be attributed to the synergism of CCR-SF and fibers in improving the particles conjunction and reducing the access of voids for soil-water interaction. Based on the obtained results, the use of optimal combination of CCR-SF with fiber can be recommended as a low cost, environmentally friendly and efficient option in improving the behavior of problematic soils and reducing their post-failure potential.**

**KEYWORDS**

**Cement stabilization, W-D cycles, deterioration of soil properties, CCR-SF-Fibers, enhanced durability.**



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## 1. Introduction

Nowadays, due to the limitation of sites with favorable geotechnical properties and of course the increase in the stress level of structures, the use of binders like cement is considered as one of the common technologies to improve the characteristics of soil [1]. Despite the widespread use of cement based-stabilization, such a method may has faced many environmental challenges, since the production of each ton of cement can release approximately one ton of greenhouse gases and as a result severe pollution of environment [2]. Moreover, the occurrence of a series of technical problems such as wetting-drying (W-D) can damage the hydration products (e.g. calcium silicate hydrate, CSH), resulting in the deterioration of soil properties [3]. In this regard, the use of industrial waste materials is an efficient idea with many positive environmental and economic aspects for soil treatment [4]. In addition, the fiber inclusion is proposed to intensify the efficiency of soil stabilization process [5]. Therefore, in the current study by performing a series of tests, including unconfined compressive strength, indirect tensile strength (ITS), electrical conductivity (EC), X-ray diffraction (XRD) and SEM-EDX analyses, the following main objectives were evaluated under various curing conditions:

I) Assessing calcium carbide residue (CCR) ability and its combination with different ratios of silica fume (SF) in enhancing the soil mechanical parameters,

II) Investigating the mechanism of soil engineering characteristics reduction upon the W-D cycles,

III) Evaluating the performance of CCR-SF and fibers mixture in comparison with cement to improve the soil durability under harsh conditions.

## 2. Materials and methods

In this study, a natural clayey soil sample with the specifications according to Table 1 was used.

**Table 1. Specifications of the used soil sample**

| Parameter | Quantity |
|---|---|
| Liquid limit (LL), % | 37.2 |
| Plasticity index (PI), % | 19 |
| Soil classification | CL |
| Specific gravity, $G_S$ | 2.67 |
| Maximum dry density, g/cm$^3$ | 1.56 |
| Optimum moisture content, % | 28.5 |
| Unconfined compression strength, MPa | 0.15 |
| Mineral composition | Mainly kaolinite |

According to the research objectives, the use of CCR alone and its combination with silica fume (CCR:SF) in four different ratios including 90 to 10, 80 to 20, 70 to 30 and 50 to 50 were considered for the improvement process. Each compound was added to the soil separately in dosages of 0 to 20% by dry weight. In order to evaluate the effectiveness of reinforcement in the stabilization process, the polypropylene (PP) fiber with an average length of 12 mm was used. Its proportion was selected as 0.75% (by weight of dry solid) according to Rozbahani et al. [2]. The well-mixed soil samples having the different amounts of agents (with and without fibers) were first prepared and then were statically placed in cylindrical steel molds, 35 mm in diameter and 70 mm in length, to achieve the maximum dry density. After the adequate times of curing under temperatures of 20 and 40 °C, the soil samples were subjected to the UCS, ITS, EC, XRD and SEM-EDX experiments.

## 3. Results and Discussion

Fig. 1 shows the strength variations of soil samples stabilized with 10% of cement after 0 to 12 cycles of wetting-drying action. As can be seen in this figure, before applying the cycles, the UCS level could reach about 2.3 MPa, which according to the ACI guidelines, indicating the successful stabilization for the light structures (such as pavement). However, the results revealed that after applying 12 W-D cycles, the UCS of samples decreased by about 60% and its value was lower than the ACI level. According to the presented results in Fig. 1, it can be concluded that the cement treatment can be vulnerable upon the w-d scenario; hence, a high dosage of binder (more than 10%) in needed to pass the ACI limit, which due to economic considerations and the possibility of a series of technical problems (like brittle behavior), it is not recommended to use such concentrations.

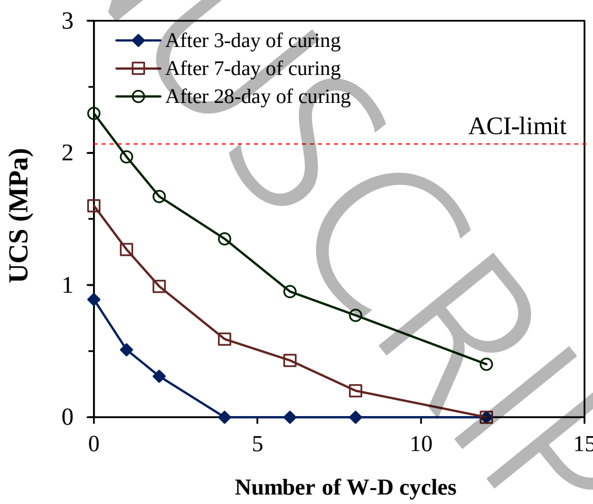


**Figure 1. Effect of W-D cycles on the strength values of cement treated soils**

Fig. 2 illustrates the UCS values for the stabilized soil samples containing 10 and 15% of CCR-SF mixture in conjunction with 0.75% fiber. For the comparison, the results of the sample containing 10% CCR-SF alone (i.e., without reinforcement) are also presented in this figure. As shown, the level of strength reduction due to W-D cycle in reinforced samples is very limited, especially with the increase of additive. In other words, the presence of CCR-SF along with the fibers has effectively increased the durability of materials. The physical appearance of the samples in Fig. 3 clearly confirms this result. Such a finding is in good agreement with the results of Pashabavandpouri et al. [1] regarding the effective role of fibers in increasing the durability of expansive soils. Other similar studies [2 and 5] also confirm the significant effect of fibers in enhancing the long-term stability of the solidified soils.

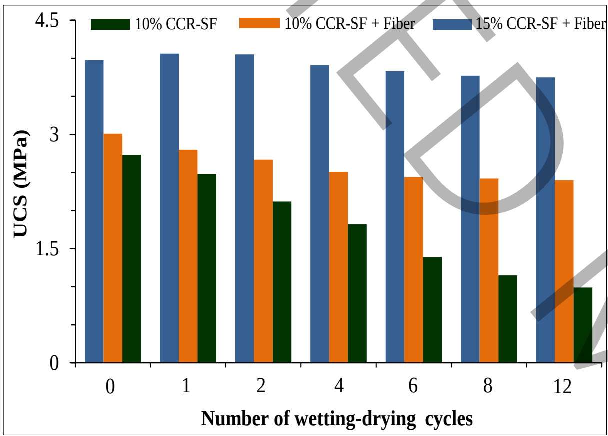


**Figure 2. Effect of CCR-SF and fiber treatment on the long-term stability of clayey soils**

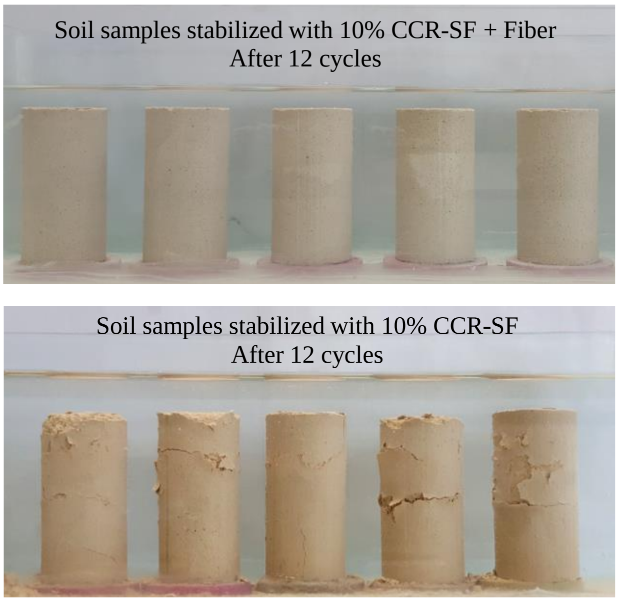


**Figure 3. Effect of W-D cycles on the physical performance of CCR-SF stabilized soil before and after fiber treatment.**

## 4. Conclusions

The most important findings of this study are given as follows:

I) The application of CCR alone had no significant impact on the engineering characteristics of the studied soil sample (mainly kaolinite) and under the same conditions, its performance was about 50% of cement. This can be ascribed to the low tendency of such a material to participate in the pozzolanic activity.

II) Despite the favorable initial performance of cement in improving the soil behavior, W-D cycles can cause a decrease and/or even complete loss of the soil bearing capacity. It was found that the W-D action did not have much effect on the quantity of cement compounds; On the other hand, with the damage of the bond between them and the particles, the formation of micro-cracks and its expansion in the matrix will cause the weakening of solidification as well as a significant deterioration in the mechanical performance.

III) The simultaneous use of CCR-SF and fibers would lead to an increase in the formation of hydrated products along with the generation of well interconnected structure, playing a prominent role in the enhancement of the soil long-term stability upon the aggressive environmental conditions.

## 5. References

[1] M.A. Pashabavandpouri, A.R. Goodarzi, S.H. Lajevardi, Enhancing the Mechanical and Microstructural Properties of Expansive Soils using Industrial Waste, Nano-material and Polypropylene Fibers: A Comparative Study, International Journal of Geosynthetics and Ground Engineering, 9(4) (2023) 54.

[2] M. Rozbahani, A.R. Goodarzi, S.H. Lajevardi, Coupling effect of superfine zeolite and fiber on enhancing the long-term performance of stabilized/solidified Pb-contaminated clayey soils, Environmental Science and Pollution Research, 30 (2) (2023) 1-16.

[3] H.R. Akbari, H. Sharafi, A.R. Goodarzi, Effect of polypropylene fiber and nano-zeolite on stabilized soft soil under wet-dry cycles, Geotextiles and Geomembranes, 49 (6) (2021) 1470-1482.

[4] M. Movahedrad, A.R. Goodarzi, M. Salimi, Effect of BOFS incorporation into calcium-based materials on solidification stabilization of a zinc-contaminated kaolin clay, Environmental Earth Sciences, 81 (18), (2022) 461.

[5] M. Safa, M., A.R. Goodarzi, B. Lorestani, Enhanced post freeze-thaw stability of Zn/Pb co-contaminated soil through MgO-activated steel slag and fiber treatment, Cold Regions Science and Technology, 210 (2023) 103826.