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Effect of addition of recycled tyre on nitrate resistance of clay

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ABSTRACT

This study investigates effect of addition of ground recycled tyre on ammonium nitrate exposed specimens by performing a significant number of unconfined compressive strength (UCS) tests when cured at different curing periods. The results showed that addition of ground recycled tyre enhanced UCS values of control and exposed specimens for all three curing periods. The microstructural analysis encompasses XRD and SEM analysis conducted on the samples and the results showed that exposure of the specimens to the ammonium nitrate cause formation of a poor connection amongst soil, cement, and ground recycled tyre particles and a reduction on hydration product generation of the cement. The results of this study showed that the ground recycled tyre is an effective replacement for cement and can successfully applied while cement contribution is reduced, and strength of the specimens have not been compromised.

1. Introduction

Portland cement (PC) is one of the most important cementitious agents that widely used to improve mechanical behaviour of problematic soils [1–3]. However, PC is an expensive and hazardous agent that its applications have been discouraged by many practitioners. Therefore, many investigations have been conducted to find a fully or partially replacement agent. Some by-products materials have been utilised and promising results have shown they could be a proper replacement for the PC. The materials such as fibre, recycled tyre, sawdust, slag, and fly ash are some of these innovative materials [4–21].

Research showed that sulphate attack is occurring on the clayey soils and can be very destructive specifically with mixture contains PC [22–24]. Sodium chloride (NaCl) or simply salt is an abundant chemical component widely exists in coastal regions. The chemical compounds such as potassium nitrate, sodium nitrate, and ammonium nitrate have sodium chloride components that when dissolved in water and exposed to PC can be very destructive as previous studies shown [25–29].

The unconfined compressive strength (UCS) test is one of the most common type of the geotechnical laboratory testing helps to understand the compressive strength of the soil. Previous studies conducted to investigate effect of different materials on compressive behaviour of the soil [30].

A review on the literature showed that previous studies conducted to investigate effect of different by-products on improvement of the NaCl contaminated soils, however there no investigation performed to investigate effect of recycled tyre as a replacement for PC.

2. Materials used

The kaolinite clay was used in this study, the pH of soil was 11 and the Gs 2.58. Fig. 1 presents the particle size distribution (PSD) of the used materials in this study. The Portland cement (PC) had pH of 12.5. Table 1 shows the characteristics of used Portland cement (PC) implemented in this study. PRT had the specific gravity (SG) of 1–1.5 g per cubic centimetre. The PSD of PRT can be seen in Fig. 1.

3. Sample preparation and methodology

3.1. Sample preparation

The sample preparation, compaction and UCS testing and the whole testing process were conducted in accordance with the Chegenizadeh et al. [10]. Table 2 shows the testing program followed to perform the tests as can be seen in Table 2. The UCS testing was conducted after fulfilling three different curing periods of 7, 14 and 28 days.

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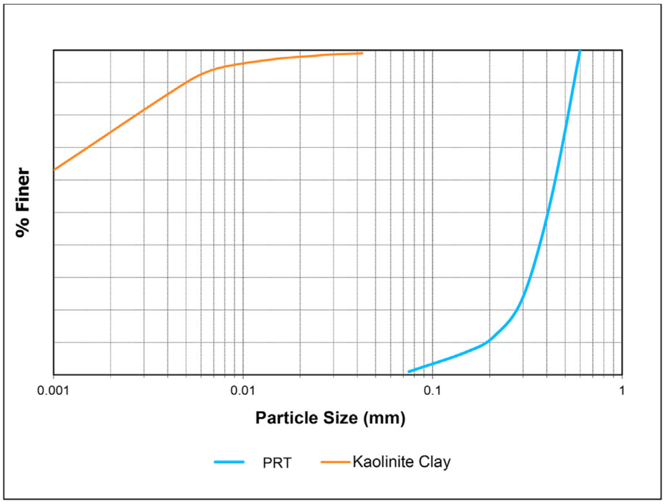

Fig. 1. Size characterization of the used soil and PRT.

Table 1
Characteristics of the used materials in this study [31].

Characteristics	Quantities
Type	II
specific gravity	2.5–3.2
pH	12
Gypsum	3–8%
Limestone	0–5%
granulated blast furnace slag	0–5%
Portland cement.	less than 97%

Table 2
Mixtures and testing program used in this study to perform the tests.

Specimen Id	PRT (%)	Portland Cement (%)	Curing (days)
K	0	0	0
2PC	0	2	28, 7, 14
3PC	0	3	28, 7, 14
4PC	0	4	28, 7, 14
2PC-10T	10	2	28, 7, 14
3PC-10T	10	3	28, 7, 14
4PC-10T	10	4	28, 7, 14
2PC-20T	20	2	28, 7, 14
3PC-20T	20	3	28, 7, 14
4PC-20T	20	4	28, 7, 14
2PC-30T	30	2	28, 7, 14
3PC-30T	30	3	28, 7, 14
4PC-30T	30	4	28, 7, 14

Table 3
Effect of PRT on compaction characteristics such as OMC and MDD.

Specimen Id	PRT (%)	Portland Cement (%)	Maximum Dry Density (gr/cm3)	Optimum Moisture Content (%)
K	0	0	1.49	23.23
2PC	0	2	1.43	23.45
3PC	0	3	1.38	24.88
4PC	0	4	1.34	25.78
2PC-10T	10	2	1.32	25.40
2PC-20T	10	3	1.19	21.69
2PC-30T	10	4	1.16	21.00
3PC-10T	20	2	1.26	25.37
3PC-20T	20	3	1.22	24.82
3PC-30T	20	4	1.18	22.49
4PC-10T	30	2	1.29	25.22
4PC-20T	30	3	1.22	23.90
4PC-30T	30	4	1.21	21.68

4. Results and discussion

4.1. Compaction tests

A series of compaction testing was performed to investigate the effect of PRT on optimum moisture content (OMC) and maximum dry density (MDD). The compaction test results can be seen in Table 3. Addition of Portland cement (PC) and PRT increases the requirement of the mixture to moisture and increase the voids in the mixture [10].

4.2. UCS test results

Figs. 2–4 shows the PRT and PC effect on UCS values before and after exposure to AN. These figures proved that with increasing in PRT and PC, the UCS values increased. The exposure of mixture of soil-PRT to AN showed that with increasing in PRT dosage the UCS values of exposed samples increased and there was more resistance while PRT added. Increasing the compressive strength of the specimens can be attributed to generation of the hydration products which helping to form strong bonds amongst soil and ground recycled tyre during the time. In fact, the hydration products such as calcium silicate hydrate (CSH) and to less extent calcium aluminate hydrate (CAH) are formed when the PC particles are exposed to the moisture and forming strong bonds with soil and PRT particles. As can be seen, the specimens containing PRT contents have a higher unconfined compressive strength in comparison with the specimens with a lower or zero PRT content which shows the effectiveness of the PRT. Also, it is obvious that exposure of the specimens into the AN concentration has reduced the UCS values to a lower range which shows the decalcification impact on compressive strength of the specimens. In this process, the existing calcium in CSH and CAH and or other hydration products are discharged and get replaced with the AN component.

Table 4, 5, 6 also shows the results of UCS before and after exposure.

4.3. Curing time effect on UCS

Figs. 5 and 6 present the effect of curing time on UCS of the unexposed and ammonium nitrate (AN) exposed samples. It can be seen from the figure that increasing in curing time promoted the UCS values. As shown in the figures, the changes were very rapid initially and the slope of changes from 14 days to 28 days was lower than 7–14 days. The compressive strength of the specimens has increased by increasing the curing period. This behaviour can be attributed to the pozzolanic reactions that occurs during the time and accelerate generation of the hydration products such as CSH as earlier indicated. This increase is more apparent in specimens with a higher PRT contents highlighting the effect of formed cementitious bonds amongst soil, ground recycled tyre and soil particles.

4.4. Microstructural analysis

The microstructural analysis including x-ray powder diffraction analysis (XRD) and scanning electron microscopic (SEM) were conducted to investigate chemical and mechanical interactions amongst material particles. For the sample of 4% PC and 10% PRT, XRD was conducted in different curing times. As can be seen, Fig. 7 legitimately connects to an expansion in top UCS. XRD examination of the AN uncovered example showed that CSH decalcified, and C-N-A-H was created after AN presentation. Figs. 8 and 9 are presented in the following. The surface changes after and before exposure was presented.

5. Conclusion

A total number of 74 UCS tests was conducted to investigate effect of

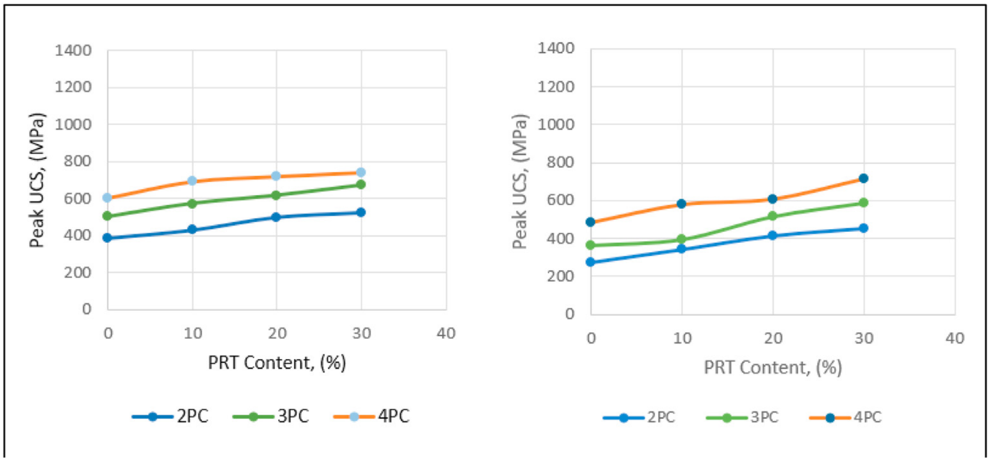

Fig. 2. PRT effect on UCS Peak values of the PC-treated Left) unexposed Right) exposed to AN (7-days curing).

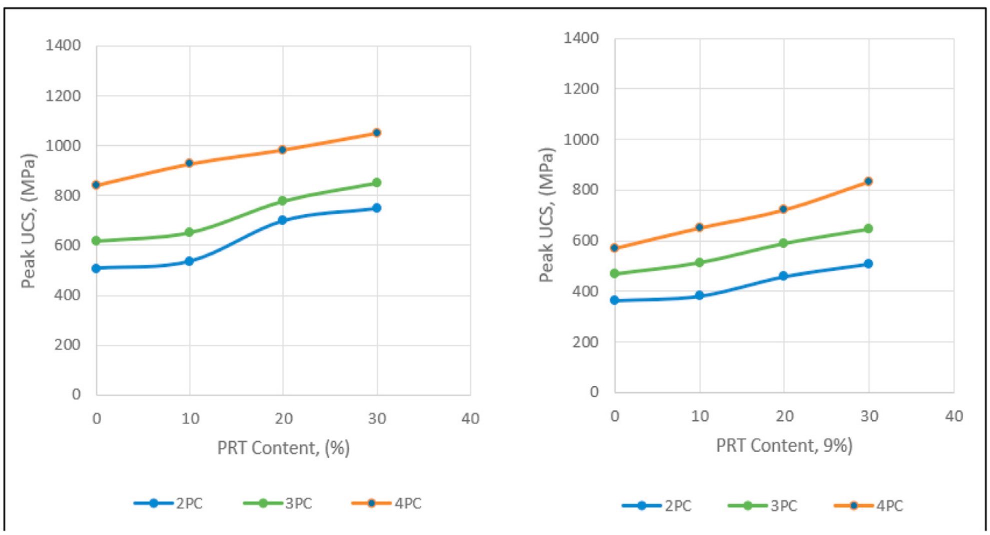

Fig. 3. PRT effect on UCS peak values of the PC-treated Left) unexposed Right) exposed to AN (14-days curing).

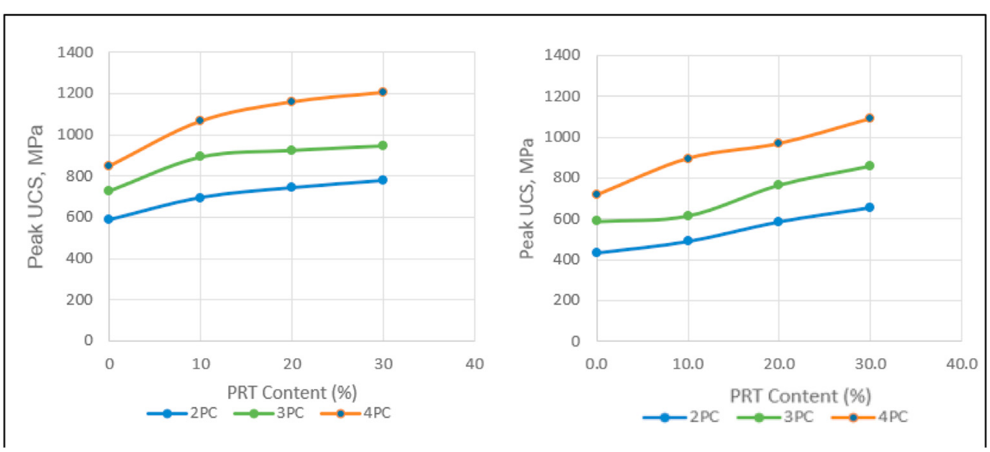

Fig. 4. PRT effect on UCS peak values of the PC-treated Left) unexposed Right) exposed to AN (28-days curing).

ground recycled tyre on improvement of the ammonium nitrate (AN) contaminated soil and the following outcomes were observed before and after exposure to AN:

- Enhancing the PRT dosage increased the UCS of both the pre-exposed and AN exposed specimen for different curing time. Formation of the strong hydration bonds (due to hydration and pozzolanic reactions)

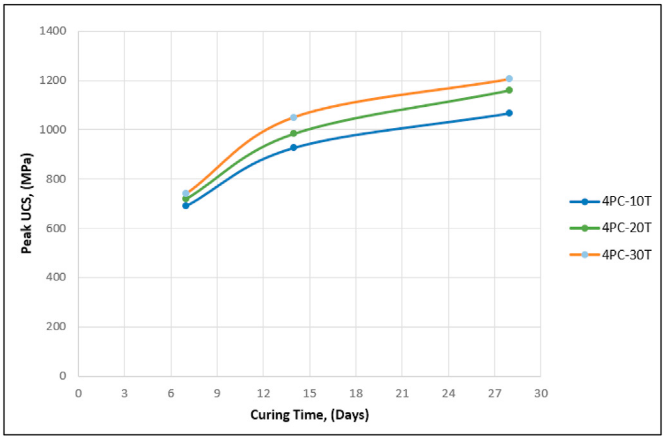

Fig. 5. UCS values at different curing time when mixed with 4% PC, and 10, 20, and 30% PRT after exposure.

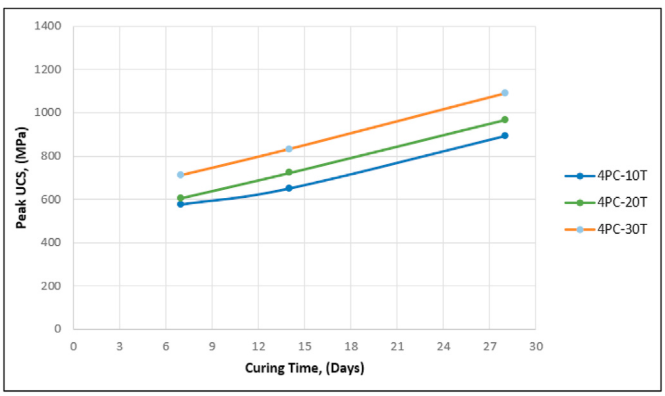

Fig. 6. UCS values at different curing time when mixed with 4% PC, and 10, 20, and 30% PRT before exposure.

amongst soil and PRT particles was the main reason for increase in compressive strength of the soil.

- Enhancing PC dosage in the PRT, clay and PC mixture caused increasing in UCS due to hydration process.
- A lower amount of increase in ammonium nitrate exposed specimens was reported. This behaviour was supposed due to the declassification and replacement of the calcium in CSH with AN component.
- Decalcification of C-S-H considered to be reason of reduction in UCS before and after exposure to AN.

Authors credit statement

Conceptualization; Amin Chegenizadeh, Mahdi Keramatikerman. Data curation; Amin Chegenizadeh, Mahdi Keramatikerman. Formal analysis; Edin Colakovic. Funding acquisition; N/A. Investigation; Edin Colacovic. Methodology; Amin Chegenizadeh, Mahdi Keramatikerman. Project administration; Amin Chegenizadeh. Resources; Amin Chegenizadeh, Hamid Nikraz. Software; N/A. Supervision; Amin Chegenizadeh. Validation; Amin Chegenizadeh, Mahdi Keramatikerman, Hamid Nikraz. Visualization; Edin Colacovic. Roles/Writing: Edin Colakovic, Amin Chegenizadeh, Mahdi Keramatikerman, Hamid Nikraz. Original draft; Edin Colakovic, Amin Chegenizadeh, Mahdi Keramatikerman, Hamid Nikraz. Writing - review & editing: Edin Colakovic, Amin Chegenizadeh, Mahdi Keramatikerman, Hamid Nikraz.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rineng.2020.100147.

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