Mechanical properties of pervious concrete prepared from recycled aggregates treated by three methods

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INTRODUCTION

Nowadays, every country produces a large amount of construction waste every year, which is not only difficult to handle but also a huge waste of resources (Naseri et al. 2022). Recycling construction waste and applying it as recycled aggregates (RA) in construction can bring huge economic and environmental benefits (Ma et al. 2022). Pervious concrete (PC) is also an environmentally friendly road construction material that can help cities quickly remove stagnant water and mitigate the heat island effect (Strokova et al. 2022). Applying RA to PC to form recycled aggregate pervious concrete (RAPC) can bring the above-mentioned comprehensive effects and has a good future for application. But the combination of PC and RA leads to worse mechanical properties of RAPC (Yang et al. 2022). Therefore, it is necessary to find a way to treat RA so as to increase the performance of RA and improve the mechanical properties of RAPC.

This study employs three different methods to treat RA: sodium silicate-silane composite modification (SS), volcanic ash slurry modification (VS), and a combination of volcanic ash slurry and sodium silicate-silane composite modification (VS-SS). Subsequently, PC is prepared using the treated RA to investigate the impact of these three treatment methods on the mechanical properties of RAPC.

MATERIALS AND METHODS

Materials

The type 42.5 Ordinary Portland Cement was used as a cementitious material for permeable concrete. Additionally, to improve the performance of concrete, Grade I fly ash was also used. Recycled Aggregate (RA) is a 4:6 mixture of crushed bricks and crushed concrete. Natural coarse aggregates (NA) were prepared using limestone. The particle sizes of both RA and NA were 4.75-9.5 mm. In addition, sodium silicate, silane, and zeolite powder were also used as the treatment materials.

The mix proportions of PC prepared with natural aggregates are shown in Table 1. Then URAC-40%, URAC-50% and URAC-60% were prepared by replacing 40%, 50% and 60% of NA with untreated RA, respectively. And SSRAC, VSRAC and VS-SSRAC were obtained by replacing 50% of NA with RA treated by the three methods, respectively. It is also worth noting that additional water of 50% of the water absorption of the RA was added to the mixing process of the RAPC to ensure the workability.

Table 1 Details of landfill subjected in this study

No.	NA/%	RA/%	W/B	Fly ash/%	Water reducer/%
NAC	100	-	0.3	20	0.7

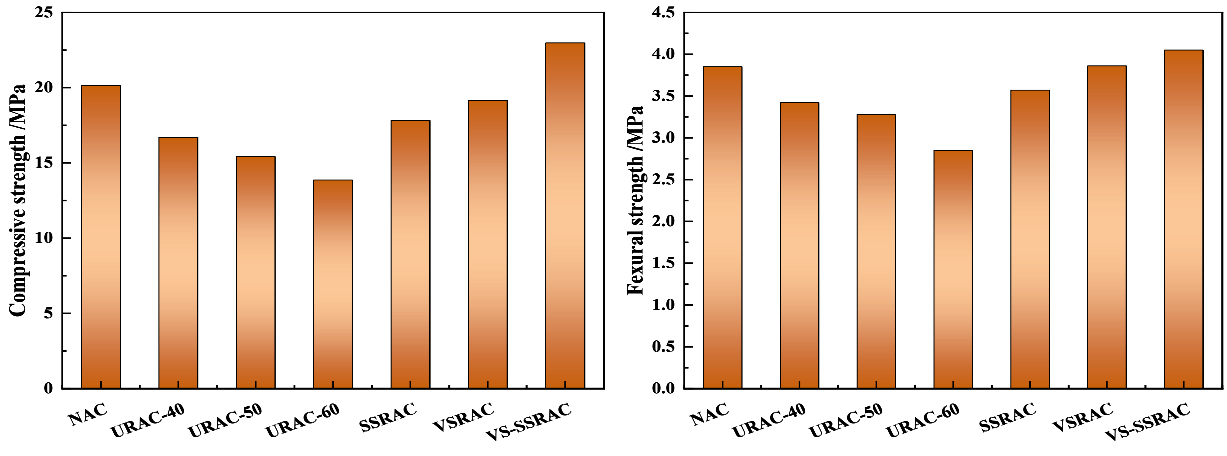
Mechanical Performance Test

The compressive strength tests and flexural strength tests were carried out with cubic specimens and beam specimens, respectively, after the specimens were formed and maintained for 28 d. The experiments were conducted with reference to Chinese standards (GB/T 50082-2009).

RESULTS AND DISCUSSION

Mechanical Performance of the RAPCs

Figure 1 shows the compressive and flexural strengths of RAPCs.



(a) (b)

Figure 1 The (a) compressive strength, and (b) flexural strengths of RAPCs

As shown in Figure 1, the strength of PC was significantly reduced after RA was added, and continued to decrease with the increase of RA dosage. The compressive strength of PC was reduced by 17.09%, 23.45% and 31.15% compared with that of NAC when the RA dosage was 40%, 50% and 60% respectively. The flexural strengths of URAC-40, URAC-50 and URAC-60 were reduced by 11.17%, 14.81% and 25.97%, respectively, compared to NAC. The reasons for the reduction of PC strength caused by RA are mainly in the following aspects. (1) RA has poor mechanical properties, crushing value is low, so the strength of PC prepared by RA is low. (2) The strength of PC is more dependent on the role of skeleton embedding compared to ordinary concrete due to its large porosity. However, RAs have complex morphology, more mutual point contact and less face contact compared to NA. Therefore, the mutual embedding of RAs has a weaker supporting effect on strength, which makes its permeable concrete strength lower. (3) Unreinforced RA absorbed part of the mixing water due to its high water-absorption, resulting in insufficient free water and insufficient hydration in the cement paste, and therefore its cement matrix strength is lower.

Meanwhile, the compressive strengths of PCs prepared from RAs strengthened by the three methods were improved to different degrees, with SSRAC, VSRAC, and VS-SSRAC improved by 15.64%, 24.61%, and 49.06%, respectively, compared with URAC-50. However, the compressive strengths of SSRAC and VSRAC were still lower than that of NAC by 11.48% and 4.9%, respectively, and only VS-SSRAC improved by 14.11% compared to NAC. It is clear that the improvement of compressive strength of RAPC by VS and SS is still limited, and only VS-SS has the most significant improvement of compressive strength of RAPC. The improvement effect on flexural strength was basically the same as that of compressive strength, with VS-SSRAC > VSRAC > SSRAC, which increased by 8.84%, 17.68% and 23.48%, respectively, compared with URAC-50. The difference is that only the flexural strength of SSRAC is 7.27% lower than that of NAC, while the flexural strengths of VSRAC and VS-SSRAC are both improved compared to NAC by 0.26% and 5.20%, respectively.

All three reinforcement methods improve the mechanical properties of RA to a certain extent, and therefore have a certain enhancement effect on the compressive strength of PC. In addition, the water absorption of RA reinforced by the three methods was reduced, and the hydration of water in the cement slurry was adequate, so the strength of the cement matrix was also enhanced, which was also conducive to the strength development of PC. Furthermore, silicate colloids, the hydrolysis product of sodium silicate, were present on the surface and in the pores of RA reinforced by SS and VS-SS, which were able to interact with the cement hydration products, C-S-H and C-A-S-H, and thus strengthened the interfacial structure between the aggregate and the cement matrix. The morphology of RA was improved after reinforcement by volcanic ash slurry wrapping, which led to the enhancement of skeleton embedding between aggregates, thus providing stronger support for the strength of PC. But the morphology of aggregates was basically unimproved by the composite reinforcement of SS, and thus the support strength provided by skeleton embedding in SSRAC was still low.

CONCLUSIONS

This study is mainly aimed at solving the problem of poor mechanical properties of RAPC, three methods were used to treat RA and the mechanical properties of PC prepared from treated RA were investigated. The test results show that the doping of RA had obvious adverse effects on the compressive and flexural strengths of PC, but the mechanical properties of SSRAC, VSRAC and VS-SSRAC reinforced by the three methods were significantly improved, and the mechanical properties of VS-SSRAC had the best improvement effect, followed by VSRAC, and finally SSRAC.

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