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The Effect of Different Admixtures on the Basic Properties of Recycled Pervious Concrete

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In this paper, we tested the effects of different admixtures at different dosages on compressive strength and water permeability of recycled pervious concrete. Through the research status-quo analysis of recycled pervious concrete at home and abroad, we determined the mix ratio for test use: water-cement ratio of 0.28, design porosity of 20%, recycled aggregate gradation of 5-10mm and 15-20mm, respectively. The effects of different admixtures at different dosages (i.e. fly ash, silica fume, polypropylene imitation steel fibres) on compressive strength and water permeability were investigated. The results show that all of the three admixtures can simultaneously increase the compressive strength to a certain extent and decrease the permeability coefficient. Our research findings provide an alternative of admixtures and their dosage in promoting the practical utilization of recycled pervious concrete.

1. Introduction

With the development of urbanization in China, urban demolition and engineering transformation caused a lot of waste concrete, urban waterlogging problem also caused a huge loss of property. The use of construction waste broken processing of recycled aggregate, to study the preparation of recycled aggregate permeable concrete. On the one hand make full use of recycled aggregate, to solve some of the construction waste disposal problems, while reducing the mining of natural aggregates to protect the ecological environment. On the other hand, to play a role in improving the ecological environment of pervious concrete to reduce the problems caused by urban waterlogging (Marsh, 2003; Xu et al., 1998; Poon and Chan, 2005; Hansen and Johannesen, 1997).

Pervious concrete is a porous, lightweight concrete made of aggregate, cement and water, containing a little or no fine aggregate. It has a cellular structure with evenly distributed pores between the slurry-wrapped aggregate (Lo and Cui, 2004; Li and Yao, 2001; Pindado et al., 1999; Collins et al., 1999). Recycled aggregate concrete is also known as recycled concrete, in which natural aggregates (e.g. sandstone) are partly or wholly displaced by recycled aggregates that are prepared by breaking, rinsing and sieving waste concrete blocks (Yu and Teng, 2013; Juan and Gutierrez, 2009; Zega et al., 2010; Etxeberria et al., 2007; Raoet al., 2007; Tang et al., 2016; Mah et al., 2017).

Recycled pervious concrete are prepared by replacing natural aggregate with recycled aggregate and mixing it with other constituents of pervious concrete. It not only satisfies the performance requirement of permeability, but is also helpful in improving luminous environment, cooling the environment, reducing noises and preserving groundwater resources. With the effective usage of waste concrete in preparing recycled pervious concrete, there will be less construction wastes to pollute the environment (Seung et al, 2005; Liv et al, 2005; Jing and Guo, 2003; Pratt, 1999).

In this paper, we tested the effects of different admixtures (fly ash, silica fume, polypropylene imitation steel fibres) at different dosages on compressive strength and water permeability of recycled pervious concrete.

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2. Test materials

2.1 Test material

Coarse aggregate is divided into recycled coarse aggregate and natural coarse aggregate: the former one is broken concrete stones provided by the Hebei Construction Group concrete mixing plant; and the latter one is broken stones purchased in the outskirts of Baoding city. The structure of the permeable concrete skeleton is composed of coarse aggregate. One of the main factors influencing the strength and water permeability of permeable concrete is the particle size and aggregate gradation of coarse aggregate. In this experiment, we used three kinds of aggregate gradation: single particle size gradation 10-15mm; continuous particle size gradation 10-15mm, 15-20mm, the ratio is 1: 2; intermittent particle size distribution 5-10mm, 15-20mm, the ratio is 1: 2. The physical and mechanical properties of the coarse aggregate are shown in Table 1.

Table 1: Physical and mechanical properties of recycled aggregates

Particle size (mm)	Apparent density (kg/m^3)	Dense packing density (kg/m^3)	The 24h water absorption (%)	Porosity (%)
10-15	2701.90	1630.60	3.28	39.6
5-10,15-20	2726.80	1540.00	5.40	43.5
10-15,15-20	2776.00	1467.60	2.88	47.1

Permeable concrete forms the multi-space stacking structure through the adhesion of cement together. The force between the permeable concrete aggregate is completed by the cement slurry, and the slurry can form a uniform cement slurry film with a thickness of 0.5-1.0 mm on the surface of the coarse aggregate. Our cement is the newly-prepared Yu Ding ordinary Portland cement (at the strength of P.O 42.5) from the Hebei Great Wall Building Materials Co., Ltd. Our sand is standard river sands at the particle size of below 5mm. The superplasticizer is a polycarboxylate high performance water reducing agent, the performance index of the water-reducing agent is shown in Table 2.

Table 2: Performance index of the water-reducing agent

Water reducing ratio (%)	Gas content (%)	Shrinkage ratio 28d (%)	Compressive strength ratio 28d (%)
≥25	≤6	≤110	≥140

The polypropylene fibre (hereinafter referred to as PPTF) can improve the strength of the recycled pervious concrete, and reduce the dispersion of the mixture. Polypropylene fiber does not appear rust phenomenon. So we decided to add the polypropylene fibre The polypropylene fibre is white and wavy, at the length and tensile strength of respective 30mm and above 400MPa, The basic index of polypropylene fiber are shown in Table 3.

Table 3: The basic index of polypropylene fiber

Length(mm)	Equivalent diameter(mm)	Color	Shape	Tensile strength (Mpa)
30	0.92	white	Wave type	≥400(measured value 432)

In order to improve the workability of recycled pervious concrete, we also use silica fume and fly ash, the main performance index of fly ash and silica fume is shown in Table 4 and Table 5.

Table 4: Main performance index of fly ash

Density (kg/m^3)	Fineness (%) (≤25.0)	Water requirement (%) (≤105)	Water content (%) (≤1)	$S0_3$ (%) (≤3)
2200	22.5	102	0.6	2.55

Table 5: The indicators and the chemical composition of silica fume

SiO_2 (%)	ZrO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	Na_2O (%)	Water content (%)	Density (g/cm^3)
80-87	6-10	≤0.4	≤0.5	≤0.05	≤3	2700

2.2 Test program

In order to study the effect of different admixtures on the basic properties of recycled pervious concrete, the compressive strength and water permeability were measured to determine the optimum admixture and optimum dosage. The mix ratio was determined in accordance with the optimal mix ratios in other documents (Zheng et al, 2012; Zheng and Zhou, 2008; Nixon, 1978) and the design mix ratio in the early-stage orthogonal test. In this test, we had three mix ratios: water-cement ratio 0.28, design porosity 20 %, the aggregate gradation 5-10mm and 15-20mm (at the mass ratio of 1:2), The sand rate is 10%, water-reducing agent content 0.015%, fly ash content 0%, 7%, 14%, silica fume content 0%, 5%, 10%, PPFF content 0kg / m3, 3kg / m3, 5kg / m3, 7kg / m3 and 9kg / m3. Table 3 lists the mix ratios of recycled pervious concrete.

Table 6: The mix ratio of recycled pervious concrete

Mix ratio	Aggregate (kg)	Cement (kg)	Water (kg)	Sand (kg)	Water reducing agent (kg)	Admixture
$F_1A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	0
$F_2A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	7%
$F_3A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	14%
$G_1A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	0
$G_2A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	5%
$G_3A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	10%
$J_1A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	0
$J_2A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	3kg/m^3
$J_3A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	5kg/m^3
$J_4A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	7kg/m^3
$J_5A_1B_2C_2$	1509.20	302.09	84.59	167.69	0.45	9kg/m^3

Note: $FA_1B_2C_2$ said the admixture is fly ash; $GA_1B_2C_2$ said the admixture is silica fume; $JA_1B_2C_2$ said the blend is polypropylene imitation steel fiber. The dosages of fly ash and silica fume are equal to the mass ratio of cement; the mass unit of polypropylene imitation steel fibre is kg / m^3.

3. Test results and analysis

3.1 Test results

Table 4 shows the compressive strength and the permeability coefficient of recycled pervious concrete for 28 days with different admixtures at different dosages.

Table 7: Test results

Test No.	Dosage	Compressive strength	Permeability coefficient
F-1	0	9.02	0.85
F-2	7%	12.76	0.54
F-3	14%	14.57	0.25
G-1	0	9.02	0.85
G-2	5%	12.22	0.48
G-3	10%	15.73	0.43
J-1	0	9.02	0.85
J-2	3	20.64	0.41
J-3	5	27.68	0.52
J-4	7	15.67	0.33
J-5	9	14.05	0.45

3.2 Experimental analysis

3.2.1 Effect of different admixtures on compressive strength of recycled pervious concrete

The admixture-dependent compressive strength of the recycled pervious concrete varies is shown in Figure 1. It can be seen from Figure 1 that after adding any of the three admixtures to the recycled pervious concrete, the compressive strength is higher than otherwise, and that the compressive strength is positively proportional to the increment in admixture. The increments in compressive strength with respect to fly ash and silica fume are basically the same, while the increment in compressive strength with respect to PPTF is particularly remarkable. This is because:

(1) With fine size, fly ash functions more as a filler which densifies the concrete and resultantly enhances the compressive strength. In light of the nature of intermittent aggregate gradation in this test, the fly ash of limited amount fails to fill all the pores of concrete, meaning that the fly ash has a threshold in improving compressive strength. However, it is observable in the test that the addition of fly ash can greatly improve the cohesion of the mixture and enhance the density and evenness of slurry-wrapped aggregate. Therefore, fly ash can improve the workability of recycled permeable concrete.
(2) With fine size, silica fume also fills the gap between slurries and resultantly enhances the compressive strength. When the strength of slurry as the binding aggregate is increases, the strength of recycled permeable concrete is also increases. Meanwhile, it is observable that when adding silica fume to the mixture, the consistency is enhanced and the aggregate presents the metallic lustre on the surface. However, according to some research records, if the content of silica fume is over 10%, the concrete will show the sign of decrease in strength. Therefore, in this test, we determine the content of silica fume as 5% and 10%.
(3) Through the analysis of the test results that the addition of PPTF will greatly enhance the compressive strength of recycled pervious concrete, we conclude that PPTF performs better than fly ash and silica fume in enhancing compressive strength. This is because when PPTF-supported concrete block is pressed, PPTF will bind the concrete and prevent it from cracking. Also, the drying shrinkage effect of concrete is inhabited by PPTF, such that the concrete is in the state of polymerization. With the increase of PPTF content, the compressive strength reached the maximum value of 27.68MPa when its content reached 5kg / m3, beginning to fall down as the dosage continues to rise. This is because the recycled pervious concrete will be less mobile with the increment in PPTF. Moreover, PPTF will cluster instead of evenly distribute in the mixture when the slump test result is zero. As a result, the compressive strength shows a downward trend.

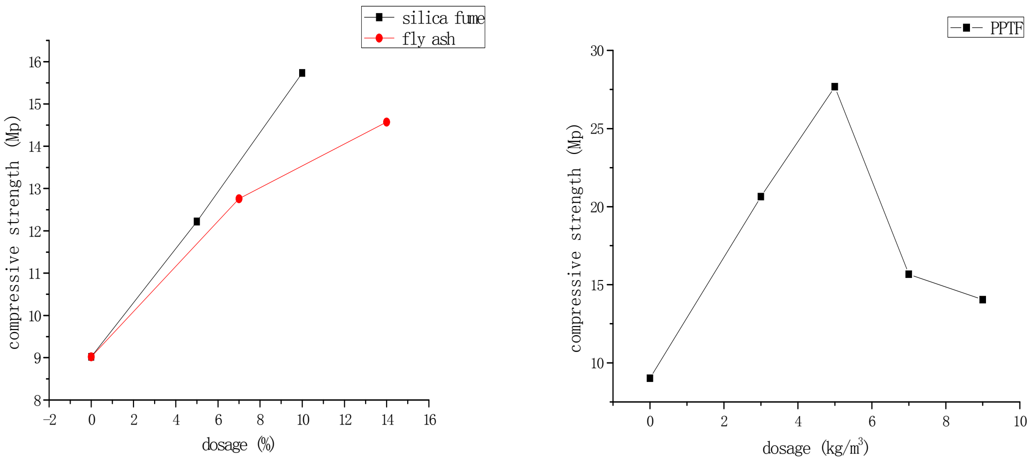

Figure 1: The effect of different admixtures on compressive strength

3.2.2 The effect of different admixtures on the permeability of recycled permeable concrete

The change law of the permeability of recycled permeable concrete with different admixtures is shown in Figure 2.
It can be seen from Figure 2 that the increment of any admixture will lower down the permeability coefficient of recycled permeable concrete, albeit different in degrees. Among them, the decline in permeability coefficient with respect to fly ash and silica fume are consistent; whereas the change of permeability coefficient with respect to PPTF is sometimes positive and sometimes negative, showing an overall declining trend.
(1) The physical activity effect of fly ash includes the effect of water reduction, micro-aggregate effect, and compact effect. The micro-aggregate effect is that the fly ash particles act as fine aggregates, so that the matching of the aggregates is more reasonable, the filling rate is increased and the dispersion of the cement is more uniform. The compact effect is that the fly ash can fill the water film and the cement skeleton gap in concrete. When the amount of fly ash is increased, the gap between the cement skeletons is denser, resulting in the filling of the pores between the coarse aggregate skeletons. Subsequently, the permeable coefficient decreases in negative proportion, i.e., the more the fly ash amount is, the heavier the water permeability decreases.
(2) When added to concrete, silica fume not only functions as a superfine filler which densifies the slurry, but also minimize pores by reacting with cements and water to generate tobermorite gels which can block the

capillaries in concrete. The recycled pervious concrete can be permeable partly because of the connected interspace between concrete pores. The silica fume additives can generate gels to block the concrete pores and accordingly reduce the permeability coefficient.

(3) Compared to fly ash additives and silica fume additives, PPTF additives are larger in size. As a result, it requires more time for water to flow through the PPTF-supported concrete, which decreases the permeability coefficient. In preparing recycled pervious concrete with additives, the feeding process is manually done, which makes it impossible for PPTF to evenly distribute in concrete. Therefore, the change of permeability coefficient fluctuates. However, as shown in Figure 2, the whole of the PPTF-supported curve of permeability coefficient lies above the PPTF-free curve.

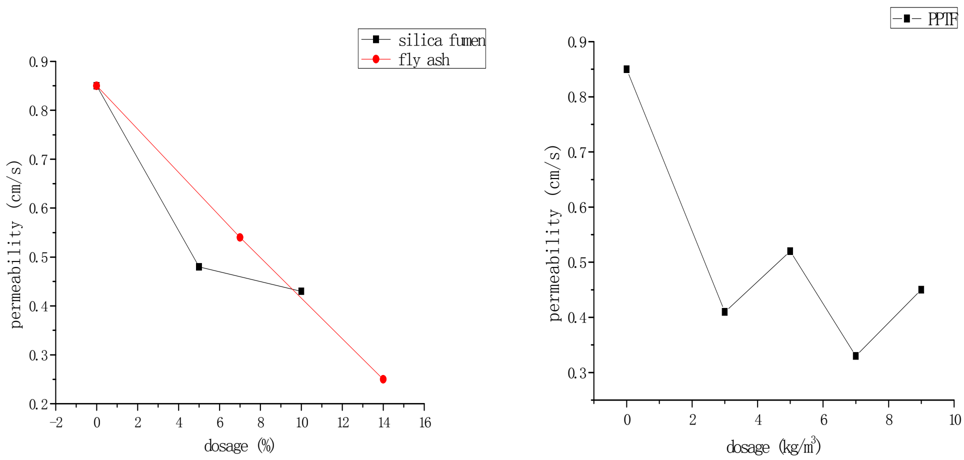

Figure 2: the effect of different admixtures on water permeability

4. Conclusions

(1) The compressive strength of recycled pervious concrete is enhanced no matter the additive is fly ash, silica fume, or PPTF, albeit to different degrees.

(2) The increments in compressive strength with respect to fly ash and silica fume are similar to each other (61.2%, 74.3%). As a comparison, the compressive strength increases much more significant when PPTF is added to the mixture. At the dosage of 5kg/m3, the increment in compressive strength is the largest (206.8%). As the PPTF dosage continues to incline, the compressive strength begins to fall down. The overall curve shape of compressive strength is parabola-like.

(3) The additives of fly ash, silica fume, and PPTF lowers down the permeability coefficient of concrete to a certain extent.

(4) With fine size, fly ash functions more as a filler which densifies the concrete and resultantly enhances the compressive strength, reducing the permeability coefficient. When added to concrete, silica fume can react with cement and water to generate tobermorite gels which blocks concrete pores and accordingly reduce the permeability coefficient. When adding PPTF to recycled pervious concrete, it requires more time for water to flow through the concrete block, such that the permeability coefficient decreases.

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