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Experimental Study on Recycled Aggregate Pervious Concrete

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***Abstract*—**Concrete is the most widely used building material in the world. At the same time, the world produces a large amount of construction waste each year. Waste concrete is processed and treated, and the recycled aggregate is used to make pervious concrete, which enables the construction waste to be recycled. Pervious concrete has many advantages such as permeability to water, protection of water resources, and so on. This paper tests the recycled aggregate obtained by crushing high-strength waste concrete (TOU) and low-strength waste concrete (PU), and analyzes the effect of porosity, amount of cement, mineral admixture and recycled aggregate on the strength of permeable concrete. The porosity is inversely proportional to the strength, and the amount of cement used is proportional to the strength. The mineral admixture can effectively improve the workability of the mixture. The quality of recycled aggregates had a significant effect on strength. Compared with concrete using "PU" aggregates, the strength of 7d and 28d concrete using "TOU" aggregates increased by 69.0% and 73.3%, respectively. Therefore, the quality of recycled aggregates should be strictly controlled during production, and the mix ratio should be designed according to different use environments and usage requirements. This test prepared a recycled aggregate permeable concrete with a compressive strength of 35.8 MPa, which can be used for light load roads and provides a reference for engineering applications.

***Keywords*—**Recycled aggregate, pervious concrete, compressive strength, permeability.

I. Introduction

CONCRETE is one of the most widely used building materials in the world. About 10 billion cubic meters of concrete is produced every year in the world and used in various construction projects. A large number of mines have been mined, natural stones are consumed and natural resources have been destroyed. Around 20 million tons of construction waste is produced around the world, of which, 6 tons of waste concrete are available. If waste concrete is used as an aggregate of concrete after processing, it can reduce mining and protect natural resources to a certain extent; however, at the present time, the utilization rate of recycled aggregate in the world is low. It is necessary to expand the application scope of recycled aggregate to increase the level of its use.

Water is an important resource, and many countries in the world are faced with serious water shortage. Water shortage has become one of the important factors that restrict the development of the national economy and society. A pervious concrete ground instead of the traditional concrete pavement can effectively protect the groundwater resources. At the same time, pervious concrete also has many advantages, such as absorbing and reducing noise, alleviating the urban heat island effect, improving the travel environment and so on. It is a kind of energy saving and environmental protection material [1]. Pervious concrete is generally used in light roads such as park roads, residential roads, and municipal squares, etc. Pervious concrete pavement is used in the road surface of the national site park of Daming Palace in Xi'an [2], China, with the use of ordinary concrete as the base, the thickness of concrete pavement is up to 30 cm. In Beijing Daxing Binhe Forest Park in China, pervious concrete is also used as a heavy-duty road [3]. But, the application of this kind of pervious concrete heavy load pavement is limited. Using recycled aggregate instead of natural aggregate, the prepared pervious concrete is used for pavement materials, which not only utilizes construction waste, but also reduces the consumption of natural stones, and allows rainwater to replenish groundwater resources through pervious concrete pavement. Therefore, recycled aggregate pervious concrete has multiple environmental and economic benefits. It is a new building material representing social progress and development [4].

In this paper, the mix ratio design of high strength recycled aggregate concrete is studied, and the influence factors of the strength are analyzed and discussed, which provides some reference for the engineering application.

II. Material

A. Cement

Use P.O.42.5. Its physical and mechanical properties are shown in Table I.

B. Aggregate

The ordinary aggregate is crushed with a diameter of 5~10 mm, and its performance is shown in Table II. In this experiment, a small jaw crusher was used to break up the ordinary concrete and pervious concrete. The recycled aggregate with a particle size of 5~10mm was screened by the test sieve, and the performance index of the recycled aggregate was shown in Table II.

C. Plasticizer

Naphthalene based superplasticizer is used in this paper.

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D. Mineral Admixture

This experiment uses silica fume and fly ash. The SiO_2 content of silica fume is 92%, and its performance indicators are shown in Table III. The grade of fly ash is grade I.

TABLE I
PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT

Performance		Test result
Density (g/cm^2)		3.1
Specific surface area (m^2/kg)		360
Setting time (h)	Initial	1.5
	Final	3.5
Flexural strength (MPa)	3d	4.2
	28d	8.2
Compressive strength (MPa)	3d	24.8
	28d	52.6

III. MIX RADIO DESIGN AND TEST RESULTS

A. Mix Ratio Design

The mix ratio design of this test is shown in Table IV.

B. Test Results

Test results are shown in Table V.

IV. INFLUENCE FACTORS OF COMPRESSIVE STRENGTH

A. Porosity

As seen in Figs. 1 and 2, the strength of concrete prepared by recycled aggregate decreases linearly with the increase of porosity. When porosity increased from 11% to 14%, 17% and 20%, the compressive strength of 7d made of PU aggregate decreased by 21.4%, 32.7% and 50.6%, and the compressive strength of 28d decreased by 23.3%, 30.6% and 47.9%, respectively. The compressive strength of 7d made of TOU aggregate decreased by 21.2%, 33.9% and 44.9%, and the compressive strength of 28d decreased by 20.1%, 36.9% and 47.8%. Therefore, under the premise of satisfying the permeability, we should minimize porosity, improve the strength of pervious concrete and prolong its service life.

TABLE II
PERFORMANCE INDICATORS OF AGGREGATE

Species of aggregate	Ordinary aggregate	PU	TOU
Particle size (mm)	5~10	5~10	5~10
Porosity (%)	41	45	47
Bulk density (kg/m^3)	1600	1380	1380
Crushing index value (%)	7	13	14
Needle like content (%)	7	2	3
mud-content (%)	0.4	0.2	0.2
Mud block content (%)	0.2	0.1	0.1

PU: Recycled aggregate obtained by crushing low-strength ordinary concrete;
TOU: Recycled aggregate obtained by pervious concrete

TABLE III
PERFORMANCE INDEX OF SILICA FUME

Performance	Test result
Loss (%)	3.5
Cl-content (%)	0.05
SiO_2 (%)	92
Specific surface area (m^2/kg)	22000
Water content (%)	1.5
Water demand ratio (%)	110
Activity index (%)	105

TABLE IV
MIX RADIO DESIGN

Number	Cement (kg)	Silica fume (kg)	Fly ash (kg)	Aggregate (kg)	Water (kg)	Plasticizer (kg)	Water cement ratio	Design porosity
Ordinary aggregate	308	--	126	1600	117	3.47	0.27	15
PU-1	394	--	169	1380	152	4.5	0.27	12
PU-2	360	--	155	1380	139	4.12	0.27	14
PU-3	324	--	139	1380	125	3.7	0.27	18
PU-4	290	--	125	1380	112	3.32	0.27	21
TOU-1	420	--	180	1380	164	4.8	0.27	12
TOU-2	384	--	164	1380	148	4.38	0.27	15
TOU-3	347	--	149	1380	134	3.97	0.27	18
TOU-4	314	--	134	1380	121	3.58	0.27	21
TOU-5	392	--	160	1380	150	4.41	0.27	15
TOU-6	365	27	160	1380	153	4.41	0.28	14

B. Dosages of Cemented Materials

It can be seen from Figs. 3 and 4 that the strength of recycled concrete is almost linearly increased as the amount of cemented material increases. When the amount of cementation is increased from 0.16 to 0.17, 0.18 and 0.20, the 7d compressive strength of concrete made from PU aggregate is increased by 36.1%, 59%, 102.4%, and the compressive strength of 28d is increased by 33.3%, 44.7% and 92.1%, respectively. The compressive strength of 7d made of TOU aggregate increased by 19.9%, 42.9% and 81.4%, and the compressive strength of 28d increased by 20.8%, 52.9% and 91.4%. The increase of cementing material can significantly increase the strength of concrete, but with the increase of cementation material, the water permeability decreases obviously. The water permeability and the concrete strength should be determined according to the rainfall in different areas. The concrete strength should be determined by the requirements of two aspects.

TABLE V
TEST RESULTS

Number	Compressive strength (MPa)		Measured porosity (%)
	7d	28d	
Ordinary aggregate	20.2	24.8	14
PU-1	16.8	21.9	11
PU-2	13.2	16.5	14
PU-3	11.3	15.2	17
PU-4	8.3	11.4	20
TOU-1	28.3	35.8	11
TOU-2	22.3	28.6	14
TOU-3	18.7	22.6	17
TOU-4	15.6	18.7	20
TOU-5	25.4	31.5	14
TOU-6	28.8	30.4	13

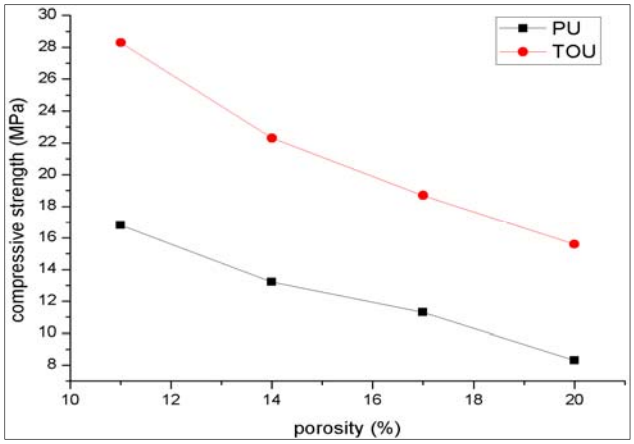

Fig. 1 The effect of porosity on the compressive strength of 7d

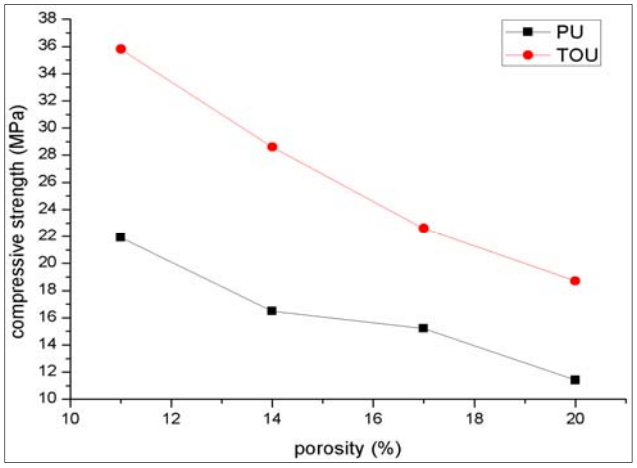

Fig. 2 The effect of porosity on the compressive strength of 7d

C. Admixture

The fly ash in recycled aggregate concrete can reduce the hydration heat of the cemented material, reduce the micro crack of the concrete after hardening, and improve the durability and reduce the cost [5]. Silica fume can increase the cohesiveness of the slurry and make the slurry more evenly wrapped around the aggregate, so that the slurry does not flow during the construction process [6]. As can be seen from Fig. 5, when the amount of silica fume is 5%, the compressive strength of concrete 7d can be significantly increased, but the compressive strength of 28d is reduced to a certain extent. In order to ensure the later strength of concrete, the amount of silica fume should not exceed 5%.

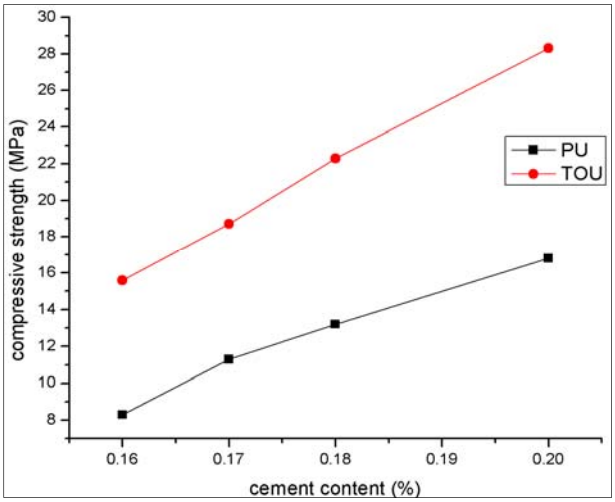

Fig. 3 The effect of the amount of cemented material on the compressive strength of 7d

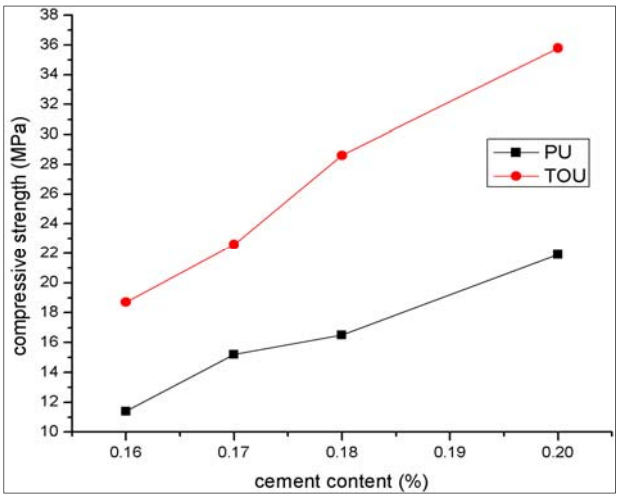

Fig. 4 The effect of the amount of cemented material on the compressive strength of 28d

D. Species of Recycled Aggregate

This is mainly due to the fact that there are more sands in ordinary concrete and the strength of hardened cement stone is lower, and the quality of recycled aggregate after crushing is poor. The pervious concrete contains no sand, and the strength of the cement stone is high. The strength of the recycled aggregate after crushing is high, and the porosity of the recycled aggregate is large. At the same porosity, more slurry needs to be filled, so the prepared pervious concrete has higher strength than ordinary aggregates. Therefore, according to the source of different recycled aggregates, if necessary, the aggregate should be cleaned, the water-cement ratio adjusted, and the amount of cement added to improve the performance

of recycled aggregate pervious concrete.

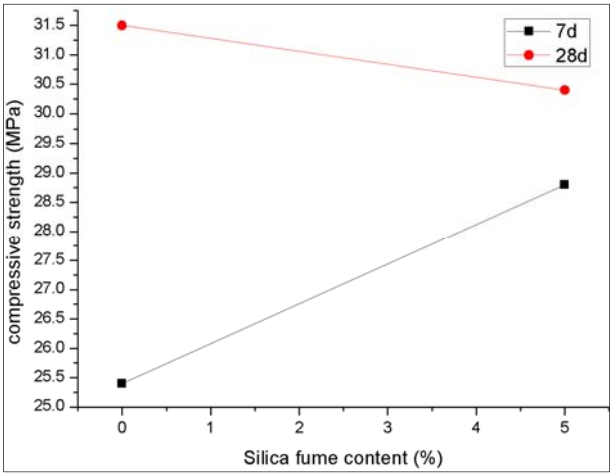

Fig. 5 Effect of silica fume on compressive strength

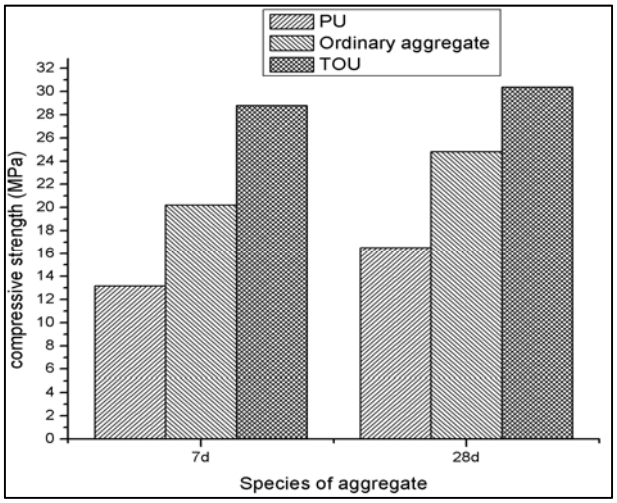

Fig. 6 The influence of the species of recycled aggregate on the strength

V. Conclusion

This test compares and analyzes the mechanical properties of recycled pervious concrete prepared from two different sources of recycled aggregate, and draws the following conclusions:

1. Factors affecting the strength of pervious concrete for recycled aggregates include porosity, amount of binder, mineral admixture, and quality of recycled aggregate. It is necessary to prepare recycled aggregate pervious concrete by selecting raw materials and optimizing mix ratio design.
2. The strength of the recycled aggregate pervious concrete prepared in this test reached 35.8 MPa, which meets the requirements for general pavement use.

The quality of recycled aggregate prepared using high-strength concrete waste is good, but it is mainly low-strength ordinary concrete in construction waste, and the strength of the original slurry obtained from the recycled aggregate is low. Therefore, it is critical to control the quality of recycled aggregate production.

To increase the utilization of construction waste and achieve sustainable development requires us to work together.

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