Experimental Study on Impermeability of Recycled Concrete and Its Security Measures

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Abstract:
Recycled concrete specimens were prepared according to different fly ash content and water-cement ratio. These specimens were respectively cured for 28d, 60d and 90d.The influence of water-cement ratio, concrete age and fly ash content on the impermeability of recycled concrete was researched through impermeability experiment. On equal terms, the result shows that the average seepage height of recycled concrete is higher than common concrete. The average seepage height increases with the increasing of water-cement ratio, but decreases with the increasing of fly ash content and concrete age. With the increasing of concrete age, the average seepage height of fly ash recycled concrete is higher than that without fly ash. Concrete age and fly ash are play a double role in improving impermeability of recycled concrete. Average seepage height of recycled concrete after treatment is much lower than untreated concrete, and the average seepage height of recycled concrete which age is 60d decreases the biggest. Proper reduction of water-cement ratio and fly ash content, increasing concrete age, pickling of recycled aggregate and other measures can effectively improve recycled concrete impermeability. Fly ash improve impermeability of recycled concrete is better than other three factors.

Keywords: recycled concrete, impermeability, average seepage height, security measures, improvement measures

INTRODUCTION

With the continuous expansion of urban construction scale and the rapid development of economy, a mass of abandoned construction waste will be produced in the demolition of houses, road renovation and civil engineering construction. These waste concrete account for 30%~40% of the total urban waste and have become principal source of urban waste [1]. Generally, the composition of waste concrete is complex and cement slurry, mortar and cracked concrete aggregate. The recycled aggregate has internal injury during the crushing process and a large amount of waste cement mortar is easy to be crushed. The defects of poor gradation, low apparent density, high porosity and high hygroscopicity of recycled coarse aggregate are caused. This directly affects the durability and strength of recycled concrete.

Scholars around the world have conducted some researches on the sustainable reuse of waste concrete over recent years, and some countries have developed corresponding technical specifications and standards to assure the engineering application of recycled concrete. A mass of abandoned concrete is reused as building material resource. It is conducive to protect the environment and solve the growing disposal crisis of construction waste. It is a project which can bring environmental protection benefits, economic benefits, social benefits and contributes to city sustainable development [2-3]. Durability is the eternal theme of concrete material performance research. Carbide, alkali-aggregate reaction, steel bar rust candle, freeze-thaw damage and permeability are closely connection with durability, it is because the permeability reflects internal pore size, quantity, distribution and connectivity of concrete. Permeability degree is directly affects the ability of concrete to resist external invasion of various media.

TESTING RAW MATERIAL AND PROGRAM

Testing Raw Material

(1) Cement: Ordinary Portland cement which strength grade 42.5 produced by Huaibei Songshan cement co., LTD, the main physical performance indexes as shown in Table 1.

Table 1. Main physical performance indexes of cement

Fineness/%	Normal consistency of water requirement/%	Setting time/min		Compressive strength/MPa		Flexural strength/MPa	
		Initial setting	Final setting	3d	28d	3d	28d
0.8	27	185	328	24.2	46.4	5.3	9.1

(2) Fly ash: Grade II ash produced by Anhui Huainan Luoneng power generation co., LTD, the main physical performance indexes as shown in Table 2.

Table 2. Main physical performance indexes of fly ash (%)

Fineness	Water demand ratio	Ignition loss	SO3 content
18.3	94	2.4	qualified

(3) Fine aggregate: Main physical properties of sand as shown in table 3.

Table 3. Physical properties of sand

Name	Fineness modulus	Apparent density kg.m-3	Packing density kg.m-3	Water requirement ratio	Intensity ratio	Assessment
Sand	2.7	2479	1423	1.00	1.00	Sand in area II

(4) Coarse aggregate: The waste concrete blocks produced in the civil engineering material laboratory are broken by a jaw crusher initially, and ensure regenerated coarse aggregate is completely dry. The coarse aggregate is shaped by a particle shaping machine, and then screened by a 4.75mm sieve. Particles larger than 4.75mm are reclaimed coarse aggregate after shaping. Main physical properties of regenerated coarse aggregate and gravel for test are shown in Table 4.

Table 4. Physical performance index of regenerated coarse aggregate and gravel

Name		Apparent density kg.m-3	Acicular content %	Water absorption %	Crushing index %
Regenerated coarse aggregate	After primary crushing	2376	8.2	2.8	17.6
	After shaping	2457	5.5	2.0	14.8
Gravel		2513	5.9	1.8	12.5

Experimental Scheme

The water-cement ratio of recycled concrete are respectively 0.40, 0.50 and 0.60, the fly ash content are respectively 10%, 20% and 30% of cement content. Put the recycled concrete specimens into standard curing room for 28, 60 and 90 days after forming. The effects of water-cement ratio, fly ash content and age on the impermeability of recycled concrete were tested. Finally, the optimum mix proportion was determined according to different fly ash content.

The regenerated coarse aggregate was immersed in hydrochloric acid solution with concentration of 3 mol/L for 72 hours. Then soak in clean water for 24 hours, and wet sieved with 4.75mm sieve. The remaining material was the final regenerated coarse aggregate. Different water-cement ratio and age of recycled concrete are designed and manufactured according to the optimal mix ratio, and its impermeability is tested.

Test Mix Ratio

The specimens are based on the commonly used C30 strength grade in this experiment, they were divided into two groups according to the treatment degree of regenerated coarse aggregate, and the untreated regenerated coarse aggregate group was divided into four groups on the basis of different age. Because regenerated coarse aggregate has high hygroscopicity, so water-cement ratio decreases. In the process of making recycled concrete blocks, water consumption should be increased. Free water to improve the fluidity of mixtures and absorbed water to improve the hygroscopicity of regenerated aggregate should be considered. Mix proportion design of regenerated coarse aggregate concrete are shown in Table 5.

Table 5. Design of cement mortar mix proportion for regenerated coarse aggregate concrete

Serial number	Water-cement ratio	Fly ash/kg		Cement/kg	Regenerated coarse aggregate /kg	gravel/ kg	sand/kg
		Weight	Dosage %				
1	0.40,0.50,0.60	0,40,80,120	0,10,20,30	400,360,320,280	0	1231	663
2		0	0		1231	0	

PERMEATION TEST RESULTS AND ANALYSIS

WaterPermeability Test

The penetration depth method was used in this test. Before the test, the concrete impermeable specimens were sealed with silica gel sleeve, and the specimens were loaded into concrete impermeability tester (HP-4.0). At constant pressure of 1.0MPa, it acts for 24 hours, and the pressure process is not more than 5 minutes. The specimens taken from the impermeability tester are placed on the press, and the specimens are broken into two halves along the longitudinal section. Waterproof pen is used to trace the water marks on the concrete section, and steel ruler is used to measure the seepage height of 10 measuring points along the water marks. The average seepage height of 10 test points is taken as the measured value of seepage height of the specimens. Then a group of six specimens arithmetic average value of the seepage height is calculated as the group specimens measured value of seepage height, so as to evaluate the water permeability of concrete.

The seepage height of a single specimen is calculated according to formula (1).

$$h_i = \frac{1}{10}\sum_{j=1}^{10} h_j \quad (1)$$

In the formula: The seepage height of ith specimen at jth measuring point. (mm)

The average seepage height of a group of specimens is calculated according to formula (2).

$$h = \frac{1}{6}\sum_{i=1}^{6} h_i \quad (2)$$

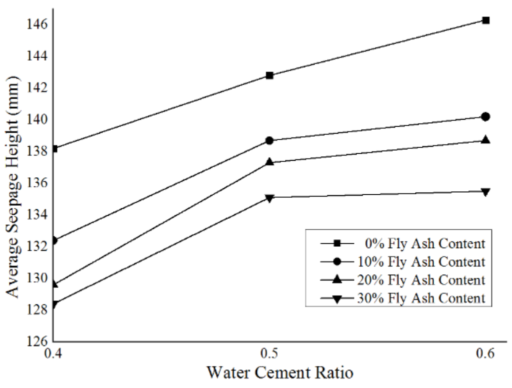
Impermeability Analysis of Recycled Concrete

Different water-cement ratio

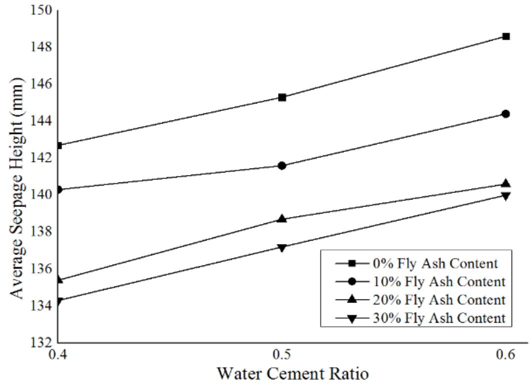
Fly ash content of ordinary concrete and recycled concrete both are 0, 10%, 20% and 30%. The average seepage height was tested in 28 days and 60 days. Experimental result were drawn as shown in Figure 1.

The curves in Figure 1 show an upward trend. Whether ordinary concrete or recycled concrete, the water-cement ratio increases, and the average seepage height corresponding increases. Compared with ordinary concrete, the average seepage height of recycled concrete is higher, maximum difference is 7.9mm. When age is 28 days and fly ash content is 20%, compared with water-cement ratio 0.4 of recycled concrete, the average seepage height of recycled concrete with 0.5 and 0.6 water-cement ratio increases by 2.44% and 3.84% respectively. When age is 60 days and fly ash content is 20%, the average seepage height of recycled concrete which water-cement ratio 0.50 and 0.60 increases by 0.07% and 0.95% respectively.

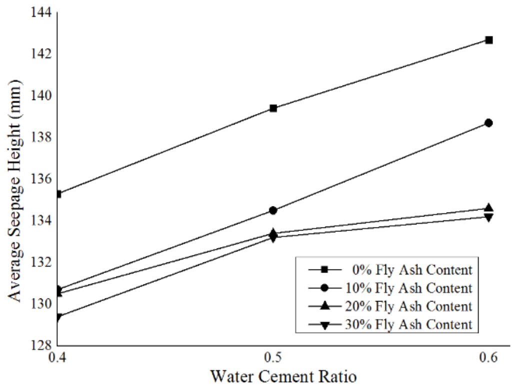
From these data, it can be seen that recycled concrete impermeability is worse than ordinary concrete, and water-cement ratio larger, higher proportion increase of the average seepage height. This is mainly because recycled concrete surface is surrounded by a large number of attached mortar, the attached mortar porosity is larger than ordinary mortar, and the cement mortar in high water cement-ratio recycled concrete is more porous. The excessive capillary pore produces many seepage channels and water can easily infiltrate into the interior of concrete under the action of constant water pressure. As a result, the average seepage height of recycled concrete is increased, which is unfavorable to the impermeability of concrete [4].



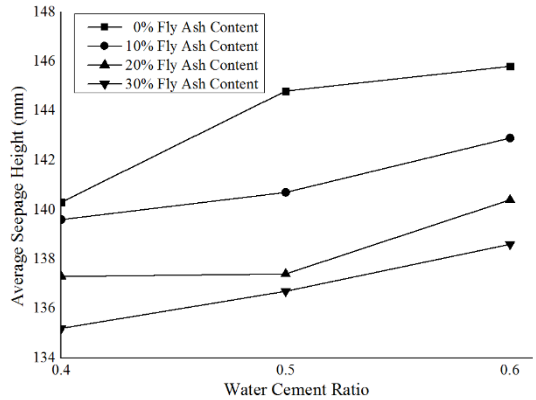
(a) Ordinary concrete (28d)



(b) Recycled concrete (28d)



(c) Ordinary concrete (60d)



(d) Recycled concrete (60d)

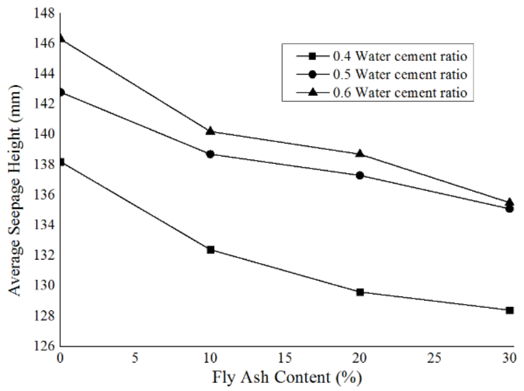
Figure 1. Effect of water-cement ratio on average seepage height of recycled concrete at different ages

Different fly ash dosage

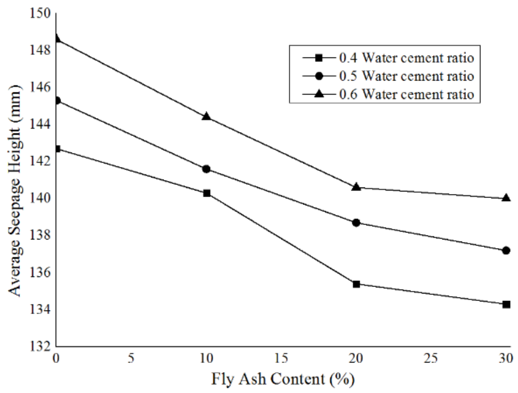
Water-cement ratio of ordinary concrete and recycled concrete both are 0.40, 0.50 and 0.60. The change of their average seepage height in 28 days and 60 days were selected to study. Experimental result are drawn as shown in Figure 2.

The curves in Figure 2 show a downward trend. whether ordinary concrete or recycled concrete, the fly ash content increases, but the average seepage height corresponding decreases. When water-cement ratio and fly ash content are equal respectively, the average seepage height of recycled concrete is 1.55%-6.81% higher than ordinary concrete. Compared with recycled concrete without fly ash, the recycled concrete average seepage height with fly ash content of 10%, 20% and 30% decreases by 2.55%, 4.54% and 5.57% respectively when age 28 days and water-cement ratio 0.50. When age 60 days and water-cement ratio 0.50, average seepage height of recycled concrete with fly ash content of 10%, 20% and 30% decreases by 2.83%, 5.11% and 5.59% respectively.

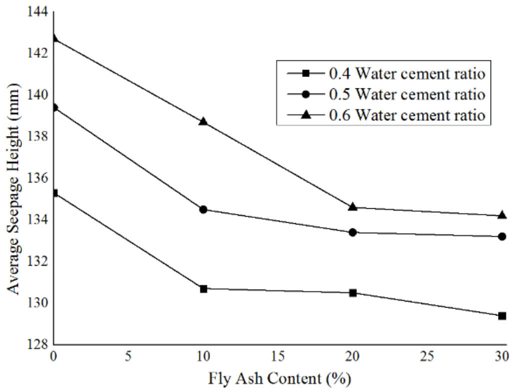
From these data we can see that, fly ash can effectively reduce recycled concrete average seepage height and improve concrete impermeability. When fly ash content reaches 20% and 30%, recycled concrete average seepage height has little difference. When fly ash content is below 30%, recycled concrete average seepage height of decreases with the increase of fly ash content. Because fly ash has active effect, morphological effect and micro-aggregate effect in concrete. Also, fly ash reduces $Ca(OH)_2$ concentration in recycled concrete. The hydrated compound produced can fill recycled concrete internal voids, effectively improve the gradation and pore size of cement material of recycled concrete. The cement stone structure becomes more compact, which delays the water penetration rate and erosion of concrete, it is beneficial to the impermeability of concrete [5].



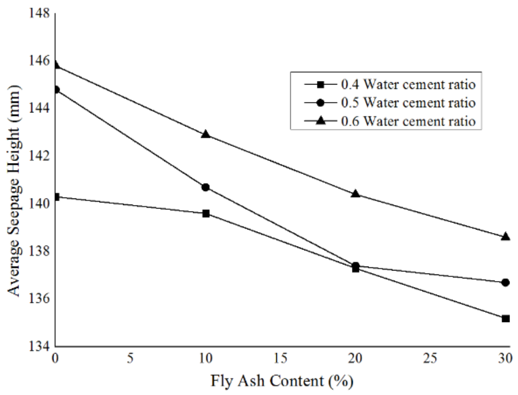
(a) Ordinary concrete (28d)



(b) Recycled concrete (28d)



(c) Ordinary concrete (60d)



(d) Recycled concrete (60d)

Figure 2. Effect of fly ash content on recycled concrete average seepage height at different ages

Different ages

When 0.50 water-cement ratio, Ordinary concrete and recycled concrete with fly ash content of 0, 20% and 30% respectively were selected to study the change of their average seepage height at different ages of 28d, 60d and 90d. The experimental results were drawn as shown in Figure 3.

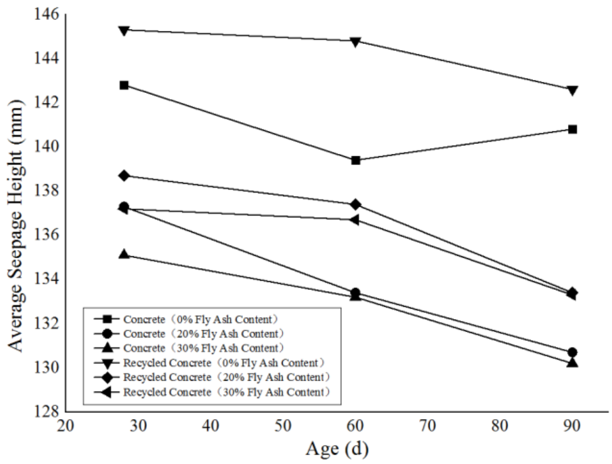


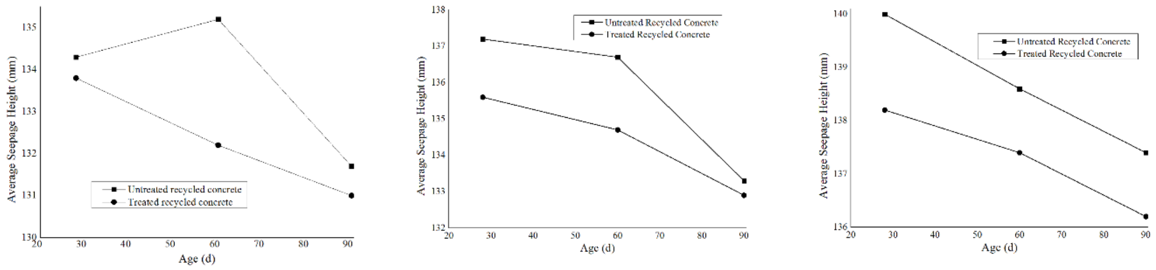
Figure 3. Effect of age on average seepage height of recycled concrete

The curves in Figure 3 show a downward trend. whether ordinary concrete or recycled concrete, the age increases, but the average seepage height corresponding decreases. Compared with 28d recycled concrete of the same age, the average seepage height of 60d and 90d recycled concrete without fly ash decreased by 0.34% and 1.86% respectively, and the average seepage height of 60d and 90d recycled concrete with 20% and 30% fly ash decreased by 0.94% and 3.82% respectively. Through data can get that age increase, recycled concrete with fly ash average seepage height is higher than ordinary recycled concrete. When fly ash content is 30%, the difference between two kinds of 60d recycled concrete is 0.6 percentage points, and the difference is as high as 1.96 percentage points in 90 days.

The average seepage height of 90-day-old fly ash recycled concrete is basically close to ordinary concrete. It is indicated that recycled concrete seepage resistance has been greatly improved with both fly ash and age promotion, and can achieve the seepage resistance of ordinary concrete. Because fly ash takes a long time in the hydration process and its hydration reaction speed is slower than cement. The result is that the recycled concrete permeability resistance is reduced. When the age reaches about 60 days, the fly ash hydration tends to be stable, and recycled concrete porosity decreases continuously, which increases the compactness and is beneficial to the impermeability of concrete [6].

Permeation test of treated recycled concrete

It is not difficult to find that fly ash and age are increase can improve the recycled concrete impermeability. Fundamentally, poor impermeability of recycled concrete is mainly due to its own defects. There are a lot of cracks and voids in the attached mortar produced in the regenerated aggregate process, which has great impact on the durability of recycled concrete. In application, appropriate measures should be taken to reduce such mortar. In this experiment, the recycled aggregate is treated by acid pickling to reduce the content of attached mortar, because acid can react with alkaline substances in attached mortar and resulting in more loose chemical products, which can be easily removed in the process of wet sieving. The average seepage height of ordinary concrete and recycled concrete with 30% fly ash in 28, 60 and 90 days were studied. The experimental results were drawn as shown in Figure 4.



(a) 0.40 WR (b) 0.50 WR (c) 0.60 WR

(WR: Water-cement Ratio)

Figure 4. Comparison of average seepage height between treated and untreated recycled concrete

As shown in Figure 4, the recycled concrete average seepage height after treatment is much lower than that of untreated concrete. The curves in Figure 4 show a downward trend. The recycled concrete seepage resistance will be enhanced with the increase of age, which is consistent with the previous experimental results. When 0.5 water-cement ratio, compared with untreated recycled concrete, the average seepage height of treated recycled concrete decreases by 1.17%, 1.46% and 0.30% respectively. The 60-day-old recycled concrete average seepage height decreases the most, it is also caused by the long hydration reaction time of fly ash.

Through this experiment, we found that on the one hand, the recycled concrete average seepage height after treatment is close to ordinary concrete, even some of the specimens are better. On the other hand, the average seepage height of two kinds of recycled concrete at the same age is very close, which shows that fly ash has strong impact on improving recycled concrete impermeability. So it can solve the impermeability problem caused by the defect of recycled aggregate [7].

CONCLUSION

(1) Due to the defect of recycled aggregate itself, under the same condition, the recycled concrete average seepage height is higher than ordinary concrete, and poor impermeability. So corresponding measures should be taken to meet the impermeability requirement.

(2) Whether ordinary concrete or recycled concrete, the water-cement ratio increases, the average seepage height increases, and the fly ash content and age increase, but the average seepage height decreases. When the age increases, the recycled concrete mixed fly ash average seepage height is higher than ordinary concrete, and the highest is 1.96 percentage points. Under the promotion of both fly ash and age, the recycled concrete impermeability has been greatly improved.

(3) The recycled concrete average seepage height after treatment is much lower than untreated concrete. The average seepage height of recycled concrete after 60 days decreases the most.

(4) These measures can effectively enhance the recycled concrete impermeability, such as reducing water-cement ratio properly, mixing fly ash, increasing age and pickling of recycled aggregate. Among them, improve the recycled concrete impermeability by fly ash is better than the other three factors. In addition, in the preparation process of recycled concrete, extend curing time to ensure the full completion of fly ash hydration reaction is necessary.

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REFRENCES

[1] Yan Sun, Kewei Sun, Yuanchen Guo. “Study on the utilization status and performance of recycled concrete”. Concrete, vol.3, pp.105-108, 2010.
[2] Jianzhuang Xiao. Recycled Concrete. Beijing: China Architecture & Building Press, 2008.
[3] Ling-ling Wang, Yanwen Chen, Wen-hao Pan. “Effects of manufacture technology on durability of recycled concrete”. Concrete, vol.11, pp.142-144, 2012.
[4] Shaomin Song, Lei Geng. “The study on impermeability and freezing resistance of high performance concrete with artificial sand”. Industrial Construction, vol.36, pp. 68-70, 2006.
[5] Shihua Zang, Jiali Fu, Huan Wu. “Experimental study on the effect of fly ash content on impermeability of recycled concrete”. Engineering and Construction, vol.28, pp.214-216, 2014.
[6] Huan Wu. “Experiment study on impermeability of modified recycled concrete”. Hefei University of Technology master thesis, pp.43-50, 2013.
[7] Gaifei Peng. “Influence of recycled aggregate defects on the durability of recycled aggregate concrete”. Beijing Jiaotong University master thesis, pp.72-75, 2013.