Experimental Study on the Workability of Recycled Fine Aggregate Concrete Cement Mortar

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***Abstract* — By preparing recycled fine aggregate cement mortar with different amounts of admixture of recycled fine aggregate and fly ash, this study is, through fluidity test, to investigate the impact on cement mortar fluidity as well as its loss made respectively by adding single recycled fine aggregate, mixing recycled fine aggregate and fly ash. It is shown that recycled fine aggregate particles, having more edges gathering a certain amount of cement paste than natural river sands, were prepared into the cement mortar which needed a greater deal of water and degraded the workability of the concrete. As the amount of admixture of recycled fine aggregate increased, the fluidity of cement mortar generally decreased in a certain extent. When the amount of admixture of recycled fine aggregate added from 70% to 100%, its fluidity respectively decreased 5.4%、9.4%、14.9%. The cement mortar prepared by single recycled fine aggregate had most loss of fluidity within 20min, which was separately up to 5.9%、6.3%、8.2% in group RA1、RA2、RA3 after a certain time. When fly ash was added into cement mortar, however, its fluidity as well as its loss, was significantly improved. As the amount of admixture of recycled fine aggregate was 70% and fly ash 10%, cement mortar showed good initial fluidity and less fluidity loss. With the increasing of the amount of admixture of fly ash, the reduction rate of cement mortar fluidity became smaller and smaller, while the loss ratio of cement mortar fluidity in the same group showed little change.**

Keywords - Recycled fine aggregate; fly ash; cement mortar; fluidity loss

I. INTRODUCTION

Twenty-first century is a high-speed period with fast developing economic construction and constantly updating urban construction, while every country in the world will generate a large amount of wasted concrete due to constructing a great number of buildings like skyscrapers, roads and bridges, etc. which statistically accounts for 30%～40% of the gross municipal solid waste, and EU countries generates 200 or 300 million tons of construction waste every year[1-3]. On one hand, waste concrete occupies much land and causes serious ecological and environmental problems; on the other hand, it gradually exhausts the natural resources due to the endless exploitation and utilization. Base on the thought of sustainable development and environmental awareness, it is undoubtedly a best choice to recycle the waste concrete after being processed.

Recycled concrete, or recycled aggregate concrete, is the concrete generated by mixing a certain proportion of cement and sand with waste concrete after being mechanically crushed, cleaned and screened. The workability of the concrete is determined by the rheological property of the mixture; the fluidity and workability of the fresh cement mortar can be used to determine the optimum volume of admixture and examine the performance of admixture as well as cement's adaptation, which provides reference for designing the mix ratio of concrete and improving the performance of admixture[4-5]. Good workability is the basic assignment to ensure that recycled concrete can be used in actual construction. However, the big uncrushed recycled aggregate is unlikely to meet the mechanized construction requirements. More studies on the industrial mass production of the recycled concrete and its construction and application to various structural components, are beneficial to decrease the transportation expenses of building materials and energy consumption, and make recycled concrete have more economical, social and environmental benefits than ordinary concrete.

II. TESTING CONDITION

A. *Testing Raw Material*

1) Cement: ordinary Portland cement produced by Huainan Shunyue cement co., LTD, strength grade 42.5; the main physical performance indexes as indicated in Table I.

TABLE I. THE MAIN PHYSICAL PERFORMANCE INDEXEX OF CEMENT

Fineness /%	Water requirement of normal consistency /%	Setting time /min		Compressive Strength /MPa		flexural strength /MPa	
		Initial setting	Final setting	3d	28d	3d	28d
0.8	27	170	310	24.4	48.6	4.7	8.8

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

TABLE II. THE MAIN PHYSICAL PERFORMANCE INDEXEX OF FLY ASH (%)

Fineness	Water demand ratio	Ignition loss	SO_3 content
18.5	93	2.3	qualified

3) Fine aggregate: firstly crush the wasted concrete specimens by mandible crusher; screen and pick out the recycled aggregate with particle size bigger than 4.75mm and re-crush them by mandible crusher; lastly reshape the recycled aggregate into recycled fine aggregate by disc crusher[6-7]. Natural sand employs river sand. The main physical performance indexes of recycled fine aggregate and natural sand used in the test, as indicated in Table III.

TABLE III. THE MAIN PHYSICAL PERFORMANCE INDEXES OF RECYCLED FINE AGGREGATE AND NATURAL SAND

Name	Fineness modulus	Apparent density $kg.m^{-3}$	Bulk density $kg.m^{-3}$	Water Demand ratio	Strength ratio	evaluation
Recycled fine aggregate	2.8	2587	1437	1.39	0.95	II area medium sand
Natural sand	2.7	2532	1376	1.00	1.00	II area medium sand

B. Testing Program

Test method for fluidity of cement mortar refers to *Test Method for Fluidity of Cement Mortar* (GB/T 2419-2005), employing NDL-3 apparatus of fluidity of cement mortar; the dosage and examination of sand refer to *Standard for Technical Requirements and Test Method of Sand and Crushed Stone (or gravel) for Ordinary Concrete* (JGJ 52-2006) and *Recycled Fine Aggregate for Concrete and Mortar* (GB/T 25176-2010). This test is, with water-cement ratio 0.5, to test the loss of cement mortar fluidity and mortar fluidity within 1h caused by two different admixture of recycled fine aggregate and fly ash.

C. Testing Mix Ratio

This test divides the specimen into three groups. Group RA is group of adding single recycled fine aggregate and in RA1、RA2、RA3, the amount of admixture of recycled fine aggregate is respectively 70%、80%、90% of the amount of fine aggregate; Group RB is group of adding mixing recycled fine aggregate and fly ash and in RB1、RB2、RB3, the amount of admixture of fly ash is respectively 10%、15%、20% of the amount of cementitious materials; Group RJ is baseline group and in Group RJ1, the amount of admixture of natural sand is 100% of the amount of fine aggregate, in Group RJ2, the amount of admixture of recycled fine aggregate is 100% of the amount of fine aggregate, and in Group RJ3, the amount of admixture of fly ash is 10% of the amount of cementitious materials and the amount of admixture of recycled fine aggregate is 100% of the amount of fine aggregate. The mix ratio among recycled fine aggregate concrete cement mortar is shown in Table IV.

TABLE IV. THE MIX RATIO AMONG RECYCLED FINE AGGREGATE CONCRETE CEMENT MORTAR (kg/m^3)

Group	Water	Cement	Recycled fine aggregate	Natural sand	Fly ash
RJ1	200	400	0	972.5	0
RJ2		400	972.5	0	0
RJ3		360	972.5	0	10%（20kg）
RA1		400	680.75	291.75	0
RA2		400	778	194.5	0
RA3		400	875.2	97.3	0
RB1		360	680.75	291.75	10%（20kg）
RB2		340	778	194.5	15%（60kg）
RB3		320	875.2	97.3	20%（80kg）

III. TESTING RESULT AND ANALYSIS

A. Fluidity of recycled fine aggregate concrete cement mortar

The fluidity of recycled fine aggregate concrete cement mortar measured according to *Test Method for Fluidity of Cement Mortar* (GB/T 2419-2005) is shown in Table V.

TABLE V. THE FLUIDITY OF RECYCLED FINE AGGREGATE CONCRETE CEMENT MORTAR

Group	Admixture ratio		Fluidity
	Recycled fine aggregate（mass fraction of fine aggregate）	Fly ash（Mass fraction of gelled material）	
RJ1	0	0	186
RJ2	100%	0	172
RJ3	100%	10%	182
RA1	70%	0	202
RA2	80%	0	191
RA3	90%	0	183
RB1	70%	10%	227
RB2	80%	15%	210
RB3	90%	20%	192

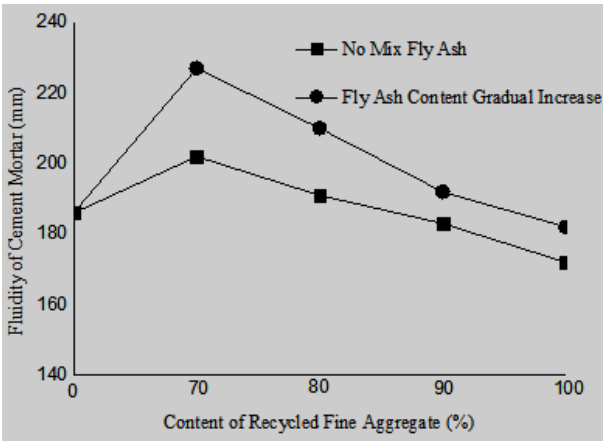

Figure1. Recycled Fine Aggregate Influence on Cement Mortar Fluidity

It is shown from Figure 1 that the fluidity of cement mortar generally lessened to a certain extent with more and more amount of admixture of recycled fine aggregate when water consumption and cement content remained unchanged and no fly ash was added. When the amount of admixture of recycled fine aggregate rose from 70% to 100%, the fluidity of cement mortar lessened respectively by 5.4%、9.4%、14.9%. This is mainly because recycled fine aggregate particles had more edges and rough surfaces attached by a certain amount of cement particles, and the workability of the cement mortar they prepare got decreased [8]. When water consumption remained unchanged, the fluidity of cement mortar also lessened to a certain extent with more and more amount of admixture of fly ash. When the amount of admixture of fly ash rose from 10% to 20%, the fluidity of cement mortar lessened respectively by 7.5%、15.4%、19.8%.

With the addition of fly ash and more admixture of recycled fine aggregate, the fluidity of cement mortar lessened on a large scale. However, it is obviously shown from Figure 1 that the fluidity broken line of recycled fine aggregate concrete cement mortar with the admixture of fly ash was above the one without he admixture of fly ash, which proved that the admixture of fly ash could improve the fluidity of recycled fine aggregate concrete cement mortar. This was mainly because fly ash particles were finer and more likely to fill the pore structures of cement hydration reaction products and then make them integrate more closely, which could replace the free water in hydrate products and improve the workability of cement-based materials as well as the rheology of cement mortar.

B. Fluidity loss of recycled fine aggregate concrete cement mortar

The initial fluidity and its loss of cement mortar with different amount of admixture of recycled fine aggregate and fly ash are shown in Table VI.

TABLE VI. THE INITIAL AND ITS LOSS OF CEMENT MORTAR WITH DIFFERENT AMOUNT OF ADMIXTURE OF RECYCLED FINE AGGREGATE AND FLY ASH

Group	The initial fluidity and its loss of cement mortar			
	0min	20min	40min	60min
RJ1	186	175	166	161
RJ2	172	152	140	132
RJ3	182	167	157	150
RA1	202	190	183	174
RA2	191	179	171	164
RA3	183	168	158	152
RB1	227	219	212	205
RB2	210	198	191	186
RB3	192	181	175	170

Figure 2 shows that the initial fluidity of cement mortar in the group with the admixture of recycled fine aggregate was higher than that in baseline group, but the fluidity loss of cement mortar was bigger than that in latter group. As the admixture of recycled fine aggregate increased, the fluidity loss of cement mortar presented a sharp rising trend. The biggest loss in Group RA happened in the opening 20min, the fluidity loss in RA1, RA2 and RA3 respectively amounting to 5.9%, 6.3% and 8.2%. When recycled fine aggregate completely replaced natural sand, the loss was up to 11.6% with a relatively steeper curve in the figure.

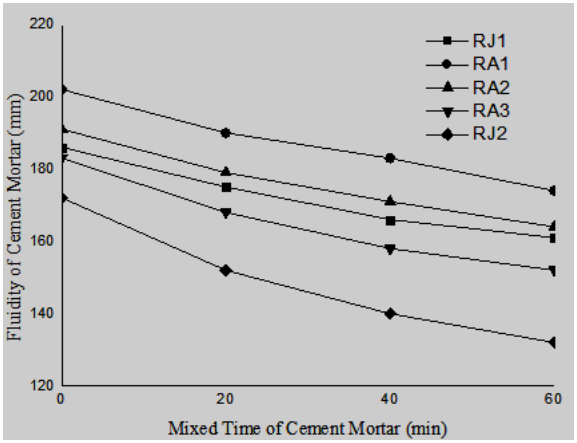

Figure2. Recycled Fine Aggregate Influence on Cement Mortar Fluidity Loss

At the time of 40min and 60min, the fluidity loss of cement mortar presented a decreasing tendency, and Group RA1 got the smallest fluidity loss as 9.4% and 13.9% respectively; Group RJ2 got the biggest fluidity loss as 18.6% and 23.3% respectively, mainly due to recycled fine aggregate having worse quality than natural sand. As the ratio of recycled fine aggregate replacing natural sand rose, water consumption grew, which strengthened the contractility of cement mortar and then enlarged its fluidity loss[9]. In addition, since in recycled fine aggregate existed pretty tiny particles, similar to limestone powder, their filling effect could replace the water in the pore structures of cement and enhanced the initial fluidity of cement mortar especially in the opening 20min, but the increasing consistency of cement mortar aggravated the fluidity loss in the later stage.

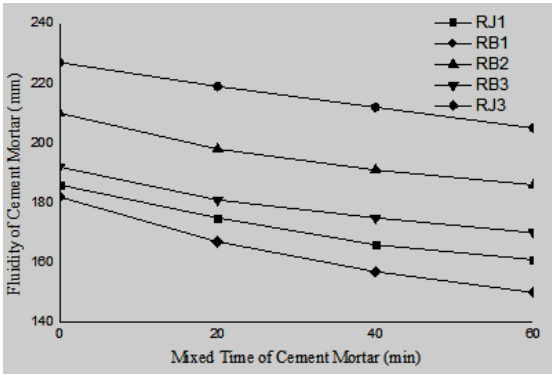

Figure3. Recycled Fine Aggregate and Fly Ash Effect of Compound Admixture on Cement Mortar Fluidity Loss

It is shown from Figure 3 that there is basically a liner trend of the influence upon the fluidity of cement mortar made from the mixing recycled fine aggregate and fly ash. Within 60 min, in Group RJ3 happened the most fluidity loss

of cement mortar up to 17.6% of initial fluidity. With 10% admixture of fly ash, the fluidity loss ratio in Group RB1 was respectively 3.5%, 6.6% and 9.7% at the time of 20min, 40min and 60min. As the amount of admixture of recycled fine aggregate increased, the loss of cement mortar fluidity in Group RB2 and RB3 began to lessen. However, due to relatively adding the admixture of fly ash, fluidity loss ratio changed slightly and the fluidity loss ratio in Group RB2 was respectively 5.7%, 9.0% and 11.4% at the time of 20min, 40min and 60min, basically equal to that in Group RB3, which demonstrated that cement mortar showed good initial fluidity and lower fluidity loss when the amount of admixture of recycled fine aggregate was 70% and fly ash 10%.

At the time of 20min, 40min and 60min, the fluidity in Group RB2 was slightly lower than in RB1, and as well RB3 was even lower. The fluidity in Group RB2 and RB3 was respectively 9.6%, 9.9%, 9.3% and 8.6%, 8.4%, 6.6%. Statically, the fluidity loss ratio of cement mortar in the same group changes slightly, mainly because the added fly ash had a good absorption performance and lessened the fluidity loss of cement mortar to give rise to better initial fluidity and lower fluidity loss[10-11]. However, when the amount of admixture of recycled fine aggregate surpassed the proper amount, the padding performance of excessive admixture of fly ash was not able to compensate the fluidity loss due to higher water demand. The water was absorbed by the recycled fine aggregate, which caused great fluidity loss of the excessive admixture of recycled fine aggregate. The improving performance of fly ash on cement mortar lay in two aspects: being mixed into cement mortar, fly ash could reduce internal friction resistance and the water; having better fineness than cement, fly ash is likely to improve the micro-aggregate gap grading and the pore structure of cement matrix, thus replacing the water to increase the fluidity, i.e. "micro-aggregate effect" [12].

IV. CONCLUSION

（1）Both recycled fine aggregate and fly ash exerted great effect on the fluidity of cement mortar. Due to carrying with fine powder, recycled fine aggregate required more water, which harmed the workability of the cement mortar; whereas, fly ash had excellent micro-aggregate effect, which could compensate the water demand of recycled fine aggregate to a certain extent.

（2）When adding single recycled fine aggregate and with its amount increased, the initial fluidity and fluidity loss of cement mortar also decreased relatively, and when the amount of admixture of recycled fine aggregate was 70%, there would be the biggest initial fluidity, lowest fluidity loss and relatively good water-retaining property.

（3）Adding mixing recycled fine aggregate and fly ash, the initial cement mortar fluidity was obviously bigger than that without the addition of fly ash, and the initial fluidity in Group RB1, RB2 and RB3 was respectively bigger than that in Group RA1, RA2 and RA3 by 12.4%, 9.9% and 4.9%, which proved that fly ash was effective in improving the rheological property of cement mortar and counteracting the large water-demanding defect of recycled fine aggregate. when the amount of the admixture of recycled fine aggregate and fly ash was respectively 70% and 10%, there would be excellent workability, which could provide reference for preparing mechanical property test specimen later.

（4）Increasing the amount of the admixture of fly ash could make smaller and smaller the reduction rate of cement mortar fluidity, and the cement mortar fluidity in the same group changed slightly. If the workability of cement mortar could be assured, consider employ the method of high amount of admixture of fly ash and low amount of admixture of recycled fine aggregate to improve cement mortar fluidity.

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