Experimental Study on the Preparation of Recycled Fine Aggregate

Weiqiu Zhong¹, Wuxu Li¹, Shengyuan Xiong¹, Aijun Zhou ² and Lintao Li¹

¹ School of Urban Planning and Municipal Engineering, Xi’an Polytechnic University, Xi’an, China
² School of Civil Engineering, Ludong University, Yantai, China
Email: zhongweiqiu@xpu.edu.cn

Abstract. In this paper, the waste concrete is used to produce recycled fine aggregate, and then different mixing quantities are used to produce ordinary mortar by replacing artificial sand. The paper makes relevant studies on the influence of the recycled fine aggregate quantity on the performance of ordinary mortar. The studies show that it is feasible to produce ordinary mortar with a certain amount of recycled fine aggregate instead of artificial sand, which can meet the requirements of relevant standards, specifications and engineering.

1. Introduction
According to incomplete statistics, construction waste accounts for about 40% of the urban solid waste, of which waste concrete accounts for 30% to 40% of the construction waste. And with the acceleration of urbanization worldwide, the demolition and renovation of existing building (structures) are increasing day by day, which will lead to the production of more and more abandoned concrete. The amount of discarded concrete will become larger and larger as the city grows, and the problem of how to deal with the fragment of discarded concrete will become increasingly serious[1].

Most of the disposal and reuse of waste concrete at home and abroad are used as recycled coarse aggregate or recycled fine aggregate after crushing, cleaning and sieving (and most of them are in the form of coarse aggregate ). At present, most recycled aggregate is used in concrete[2-6], while recycled fine aggregate is relatively less used in ordinary mortar[7-9]. In this paper, the recycled fine aggregate produced by waste concrete is used instead of some artificial sand to prepare ordinary mortar. The results show that the performance indexes of recycled fine aggregate to produce ordinary mortar meet the requirements of relevant standards, specifications and engineering use.

2. Raw Materials
The cement is PO 42.5 cement (see Table 1 for performance index). The fly ash is the second grade fly ash (see Table 2). Through mechanical crushing of waste concrete, artificial sand S1 and recycled aggregate S2 of waste concrete are obtained from a sand making yard. The performance indexes of S1 and S2 are shown in Table 3.

| Table 1. Physical and mechanical properties of cement. |
| --- |
| density / g/cm³ | 3.1 |  |
| stability (Le Chatelier soundness test) | pass |  |
| fineness (75μm sieve, /%) | 2.4 |  |
| setting time /h: min | initial set | 2.55 |  |
| | final set | 5:35 |  |
| Compressive strength /MPa | 3d | 23.2 |  |
| | 28d | 48.6 |  |
| breaking strength /MPa | 3d | 4.4 |  |
| | 28d | 7.7 |  |
Table 2. Basic properties of fly ash.

| name | Fineness(45μm sieve, %) | loss on ignition/% | water content/% | stability(Le Chateliers soundness test, /mm) | ratio of water demand/% |
|------|------------------------|--------------------|----------------|------------------------------------------|------------------------|
| Level II ash index measured value | ≤25 | ≤5.0 | ≤1.0 | ≤5.0 | ≤105 |
| | 14.2 | 0.8 | 0.2 | 2.4 | 102 |

Table 3. Technical indexes of artificial sand S1 and recycled fine aggregate.

| grain composition | accumulated retained percentage/% | grading region | name | unit | estimated value |
|-------------------|----------------------------------|----------------|------|------|-----------------|
| size of square-hole screen | S1 | S2 | 1 | 2 | 3 | |
| 9.5mm | 0 | 0 | 0 | 0 | 0 | |
| 4.75mm | 0 | 0 | 10~0 | 10~0 | 10~0 | |
| 2.36mm | 9 | 3 | 35~5 | 25~0 | 15~0 | |
| 1.18mm | 35 | 30 | 65~35 | 50~10 | 25~0 | |
| 0.60mm | 58 | 50 | 85~71 | 70~41 | 40~16 | |
| 0.30mm | 77 | 82 | 95~80 | 92~70 | 85~55 | |
| 0.15mm | 87 | 95 | 100~90 | 100~90 | 100~90 | |
| screen hole | 100 | 100 | / | / | / | |

3. Test Method and Results

3.1. Test Method
All the tests were carried out in accordance with the standard "Standard for the basic performance test method of building mortar" JGJ/T70-2009, and the mixing time was not less than 3 min with a J-15 mortar mixer.

3.2. Test Scheme and Test Results
The mix ratio of mortar is shown in Table 4, in which: fly ash is equal to replace 20% cement, and the consistency of mortar is controlled at 90 mm ~100 mm to prepare ordinary mortar. recycled fine aggregate s2 replaces artificial sand s1 with an equal amount of 0,10%,20%,30%,40%,50%,60%,70%, to study the effect of recycled fine aggregate content on the various properties of ordinary mortar, and to compare with the various properties of ordinary mortar with artificial sand s1. Its test results are shown in Table 5.

Table 4. Mortar mix ratio and test Scheme.

| order number | cement | fly ash | recycled fine aggregate | artificial sand | WJJ |
|--------------|--------|---------|-------------------------|-----------------|-----|
| 1 | 210 | 90 | 0 | 1500 | 18 |
| 2 | 210 | 90 | 150 | 1350 | 18 |
| 3 | 210 | 90 | 300 | 1200 | 18 |
| 4 | 210 | 90 | 450 | 1050 | 18 |
| 5 | 210 | 90 | 600 | 900 | 18 |
| 6 | 210 | 90 | 750 | 750 | 18 |
| 7 | 210 | 90 | 900 | 600 | 18 |
| 8 | 210 | 90 | 1050 | 450 | 18 |
### Table 5. Test Results of The effects of recycled fine aggregate on the properties of ordinary mortar.

| Order number | Water-binder ratio | Consistency /mm | Water retention /% | Setting time /h | 14d tensile bond strength /MPa | Strength /MPa 7d | Strength /MPa 28d |
|--------------|--------------------|------------------|-------------------|----------------|-------------------------------|----------------|------------------|
| 1            | 0.168              | 90               | 91.5              | 5h30min        | 0.32                          | 7.3            | 13.4             |
| 2            | 0.170              | 92               | 92.0              | 5h40min        | 0.34                          | 7.8            | 13.6             |
| 3            | 0.173              | 99               | 91.7              | 5h55min        | 0.37                          | 8.2            | 14.5             |
| 4            | 0.177              | 94               | 92.4              | 6h10min        | 0.42                          | 8.8            | 15.2             |
| 5            | 0.182              | 99               | 91.6              | 6h35min        | 0.44                          | 7.6            | 14.0             |
| 6            | 0.191              | 95               | 93.1              | 7h05min        | 0.46                          | 6.8            | 13.2             |
| 7            | 0.204              | 98               | 92.3              | 7h40min        | 0.47                          | 7.1            | 12.3             |
| 8            | 0.218              | 95               | 91.8              | 8h20min        | 0.46                          | 5.6            | 10.8             |

### 4. Analysis of Test Results

#### 4.1. Effect of Recycled Fine Aggregate Content on Water Consumption of Ordinary Mortar

It can be seen from Table 5 that when the consistency of mortar is controlled within the prescribed range (90mm–100mm), the water consumption per cubic meter of artificial mortar is the lowest when there is no recycled fine aggregate (blank sample), and the water consumption per cubic meter of mortar increases gradually with the increase of recycled fine aggregate content, especially when the amount of recycled fine aggregate is greater than or equal to 50%, the change of water consumption of mortar is obvious. This is mainly due to the fact that recycled fine aggregate is broken by waste concrete, which contains more or less part of the cement paste and some of the red brick or hollow brick or aerated block particles, it is because these parts of cement paste and part of red brick or hollow brick or aerated block particles themselves have higher water absorption (compared with stone powder in artificial sand), so the higher the amount of recycled fine aggregate, the more obvious the increase of water consumption of its mortar side by side. Combined with the data in Table 5, when using artificial sand to produce ordinary mortar, the amount of recycled fine aggregate should not exceed 40%.

#### 4.2. Effect of Recycled Fine Aggregate Content on Water Retention of Ordinary Mortar

Water retention is one of the important technical indexes of ordinary mortar, which refers to the cohesiveness and water-retaining ability of the new mortar mixture itself, and also refers to the bonding force between the various constituent materials in the mortar and the properties of no separation of materials. It can be seen from Table 5 that when the consistency of mortar is controlled within the prescribed range (90mm–100mm), the water retention of mortar is basically unchanged with the change of the amount of recycled fine aggregate under the same amount of mortar admixture, all of them are between 91% and 93%. This shows that in the artificial sand production of ordinary mortar, when the use of recycled fine aggregate instead of artificial sand, its mortar water retention has little impact.

#### 4.3. Effect of Recycled Fine Aggregate Content on Setting Time of Ordinary Mortar

Setting time is also an important index of the construction performance of mortar, which will have a large or small effect on the construction performance and hardening performance of mortar. Therefore, it is very important to study the effect of recycled fine aggregate of abandoned concrete on the setting time of ordinary mortar. It can be seen from Table 5 that when the consistency of mortar is controlled within the prescribed range (90mm–100mm), the setting time of mortar is gradually prolonged with the increase of recycled fine aggregate content, and the higher the content is, the more obvious it is. When the recycled fine aggregate content is 70%, the setting time of mortar is extended for 2h50 min. Therefore, as long as the cementitious materials (cement and fly ash) remain unchanged, with the increase of recycled fine aggregate, the free moisture in mortar will increase, thus prolong the hydration of cementitious material and ultimately affect the setting time of mortar.
4.4. Effect of Recycled Fine Aggregate Content on Tensile Bond Strength of Ordinary Mortar

Tensile bond strength reflects the bonding properties of ordinary (plastering) mortar and structure (wall). Its height directly affects the construction bonding quality of ordinary (plastering) mortar (including adhesive force, apparent quality, empty drum or cracking, etc.), especially the mortar adhesion force. The smaller the mortar adhesion force is, the more likely the wall structure is to appear such phenomena as empty drum, hemp surface, cracking and shedding. It can be seen from Table 5 that when the consistency of mortar is controlled within the prescribed range (90mm~100mm), with the increase of the amount of recycled fine aggregate, the tensile bond strength of mortar increases gradually and then basically unchanged. When the amount of recycled fine aggregate reaches 50%, the tensile bond strength of the mortar is basically stable. This is because: the existence of some cement pastes in recycled fine aggregate changes the internal structure of mortar, the cohesion of mortar itself and the binding force between slurry particles are increased. In addition, due to the high water absorption of these cement pastes, the water can be slowly discharged during the later process of mortar hardening, so that the cementitious materials can react more fully, and make the surface humidity of the wall structure change little, so that the bond strength between mortar and the structure is well developed. However, when the content of recycled fine aggregate reaches a certain value (50%), its effect has reached the highest effect, and when its content increases again, its mortar tensile bond strength will no longer be affected by this action.

4.5. Effect of Recycled Fine Aggregate Content on Compressive Strength of Ordinary Mortar

The size of the compressive strength of the mortar cube directly reflects the strength grade of the mortar, that is, the higher the strength of the mortar, the higher the strength grade, so it is indispensable to study the influence of the amount of recycled fine aggregate on the strength of the mortar. It can be seen from Table 5 that when the consistency of mortar is controlled within the specified range (90mm~100mm), the compressive strength of mortar increases gradually and then decreases gradually with the increase of the amount of recycled fine aggregate. When the content of recycled fine aggregate is 30%, the compressive strength of mortar (7d and 28d) reaches the maximum. In addition, the variation law of 28d compressive strength was basically the same at 7d. This is because: the existence of some cement pastes in recycled fine aggregate changes the internal structure of mortar, the cohesion of mortar itself and the binding force between slurry particles are increased. In addition, due to the high water absorption of these cement pastes, the water can be slowly discharged during the later process of mortar hardening, replenishing some of the moisture volatilized from the slurry and making the cementitious material react more fully, thus increasing the compressive strength of the mortar. However, when the content of recycled fine aggregate reaches 30%, the water consumption of the mortar increases greatly, the water-cement ratio changes greatly, and the compactness of the mortar hardening structure becomes worse, thus reducing the compressive strength of the mortar. Moreover, the higher the content of recycled fine aggregate, the more significant the reduction of compressive strength of the mortar.

5. Conclusion

(1) The effect of recycled fine aggregate on the working performance of mortar: with the increase of the amount of recycled fine aggregate, the water consumption of one cubic meter of mortar increases gradually, and the higher the amount of mortar, the more obvious it is; the water retention of mortar is basically unchanged, between 91% and 93%; the setting time of mortar is gradually prolonged, and the higher the more obvious the amount of mortar.

(2) The effect of recycled fine aggregate on the mechanical properties of mortar: with the increase of recycled fine aggregate content, the tensile strength of mortar increases gradually and then basically unchanged. When the amount of mortar reaches 50%, the tensile strength of mortar is basically stable; the compressive strength of mortar increases gradually and then decreases gradually, and the compressive strength of mortar (7d and 28d) reaches the maximum value when the amount of mortar is 30%. In addition, the variation law of 28d compressive strength is basically the same as that of 7d compressive strength.

(3) It is feasible to use recycled fine aggregate instead of artificial sand to produce ordinary mortar, which can meet the requirements of relevant standards, specifications and engineering.
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