Effects of Improving Recycled Fine Aggregate by Ball Mill

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Synopsis

The recycle fine aggregate is not much used for a concrete material, because of its low quality. In order to improve its quality, therefore, both a ball mill refinement and a mixing with an ordinary fine aggregate have been conducted. The effect of each improvement and the influence of the recycled fine aggregate strength are discussed based upon the obtain relation between the recycled fine aggregate quality and the mortar properties used the aggregate. As a result, the ball mill treatment could draw its shape improvement to some degree. The recycled fine aggregate strength could, moreover, hardly affect recycled aggregate mortar properties.

KEYWORDS: recycled fine aggregate, high quality treatment, ball mill, mortar property

1. Introduction

It is important to recycle demolished concrete from a view of saving natural resource. We should turn attention to its recycle for concrete materials, although most of them recycle for base-course material or backfills in present. Among the recycled products for concrete material, it is commonly said that the quality of recycled fine aggregate is inferior to that of the recycled coarse one [1]. Some high quality treatment, therefore, should be required to adequately use the former, such as a ball mill refinement and a mixing with an ordinary fine aggregate.

In this study, the usage of the recycled fine aggregate are discussed based on the observed influences of its quality on recycled aggregate mortar properties though three laboratory tests having the following tasks: (1) To examine the influence of a ball mill refinement degree on both properties of it and the mortar mode of it; (2) To compare the effect of the ball mill refinement with that of a mixing with an ordinary fine aggregate; (3) To examine the influence of its strength, which is strength of original mortar to be demolished to obtain the recycled fine aggregate, on recycled aggregate mortar properties.

Table 1 Materials of original concrete

Material	Summary	Qualities
Cement	Normal Portland cement	Density: 3.15 kg/ℓ
Fine aggregate	Crushed sand produced in Takatsuki city	Density: 2.66 kg/ℓ Water absorption: 1.4% Fineness modulus: 2.72
Coarse aggregate	Crushed stone produced in Takatsuki city	Density: 2.68 kg/ℓ Water absorption: 1.1%

Note: Concrete was used with air-entrained and water-reducing admixture

Table 2 Mix proportions and properties of original concrete

W/C (%)		58
s/a (%)		47.8
Slump (cm)		12.4
Air content (%)		6.7
Compressive strength (N/mm^2)	Standard curing (28days)	40.4
	Atmospheric curing (107days)	41.3

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Table.3 Properties of RF0

Average density (kg/ℓ)	Average water absorption (%)	Percentage of absolute volume(%)	Fineness modulus
2.37	7.8	64.7	3.17

Note: Values except Fineness modulus were measured after adjustment of the crushed sand grading.

Table 4 Mix proportions of mortar (in volume)

W/C(%)	W(ℓ/m^3)	C(ℓ /m^3)	S(ℓ /m^3)
40	316	251	432
50	318	202	478
60	317	168	514

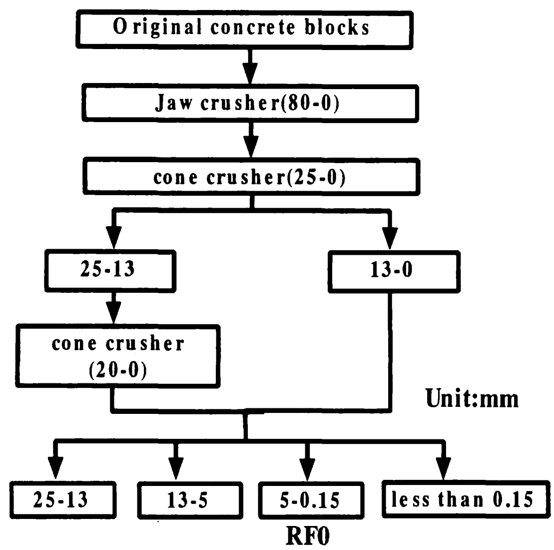

Fig.1 Flow for producing RF0 from original concrete

2. Treatment 1: Ball Mill Refinement

2.1 Original Recycled Fine Aggregate

Qualities of materials and mix proportions of original concrete are summarized in Tables 1 and 2. Volume of produced concrete was 1 m^3, which consisted of 20cm×20cm×10cm×250 blocks. After cured in the atmosphere for 3 months, those were broken according to the process shown in Fig. 1. Then the demolished concrete was sieved due to pick up recycle fine aggregate. This recycled fine aggregate is called, herein, as RF0. Its properties are show in Table 3. Here, water absorption and density of recycled fine aggregate are called average water absorption and average density, because the recycled fine aggregates are composed of particles with variant properties. The grading of the recycled fine aggregates, furthermore, was adjusted to that of the crushed sand, which fineness modulus is 2.70, when average density, average water absorption and percentage of absolute volume of RF0 were measured. Moreover, all average densities were in saturated surface-dry condition.

2.2 Test Procedures

A ball mill regulated by JIS M 4002-1976 was used to improve qualities of the recycled fine aggregate. 5kg of RF0 were put into the ball mill with some steel balls and revolutions were given up to 4000 times. After the treatment, average density, average water absorption, particle size distribution, percentage of absolute volume and recovery percentage were measured on each refined recycled fine aggregate. Then mortars were made with the recycled fine aggregate treated RF0 on degrees of 0, 1000, 2000 or 4000 times revolutions of the ball mill. Qualities of the mortar were examined through air content and mortar flow tests at fresh mortar, and compressive, splitting tensile and bending strength tests at hardened mortar. Each test method accorded with Japanese Industrial Standers. The grading of the recycled fine aggregates used in these tests was adjusted to that of the crushed sand at average density, average water absorption and percentage of absolute volume tests and also do it at making mortar. Mortar was mixed of normal portland cement according to JIS R 5201.Mix proportions of mortar are shown in Table 4.

2.3 Results and Discussions

(1) Properties of Improved Recycled Fine Aggregates

Figures 2, 3 and 4 summarize the properties of the improved RF0 on some degrees of the ball mill refinements. The average density increased and the average water absorption decreased with increasing the number of the ball mill revolutions. Its revolution numbers increased, furthermore, the fineness modulus was smaller and the recovery percentage was lower. Figure 5 shows that the recovery percentage was proportional to the average water absorption. In Fig. 6, grading of the refined recycled fine aggregates was compared with middle value of particle size distribution regulated by Japanese Industry Standard. Large number of the revolutions made particles of recycled fine aggregate

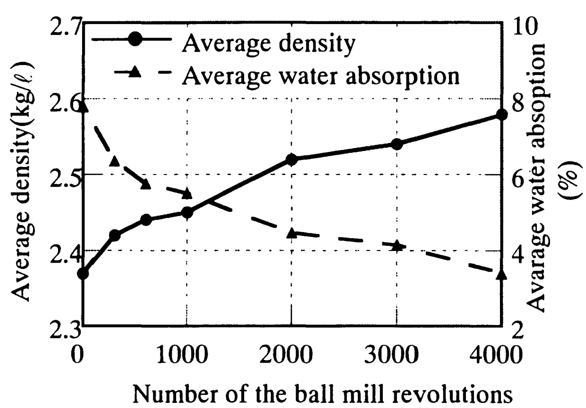

Fig.2 Influence of number of revolutions on average density or average water absorption

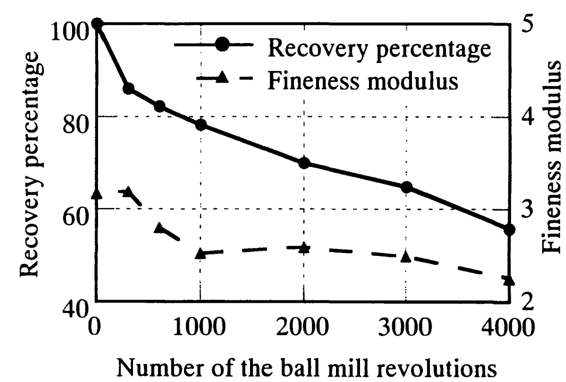

Fig.3 Influence of number of revolutions on fineness modulus or recovery percentage

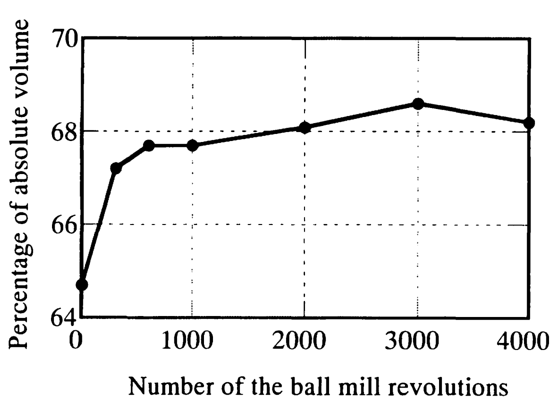

Fig.4 Transition of percentage of absolute volume

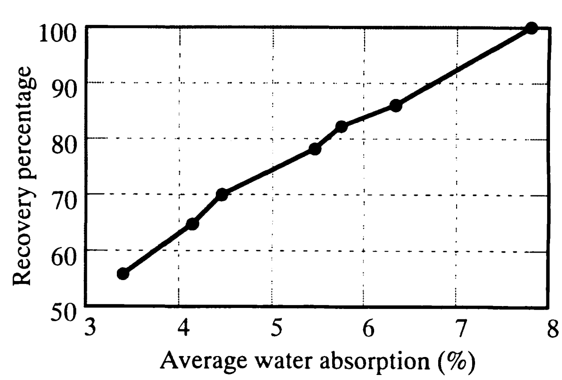

Fig.5 Relations between recovery percentage and average water absorption

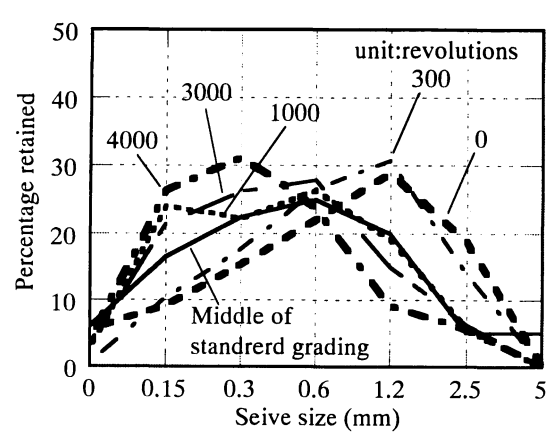

Fig.6 Transition of grading of the improved recycled fine aggregates

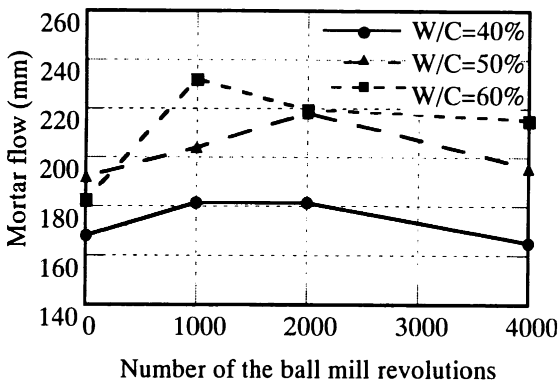

Fig.7 Relations between number of the ball mill revolutions and mortar flow

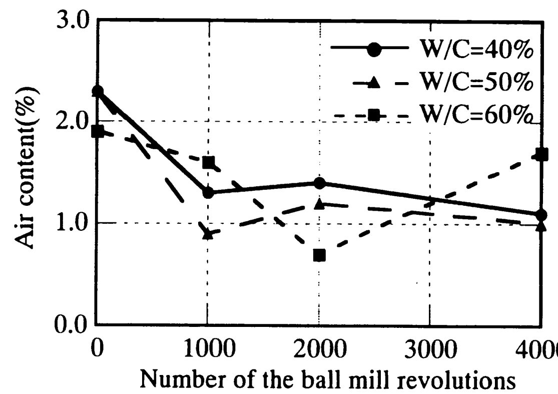

Fig.8 Relations between number of the ball mill revolutions and air content

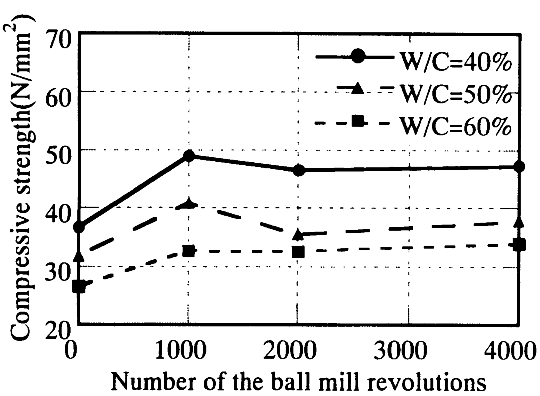

Fig.9 Relations between number of the ball mill revolutions and compressive strength

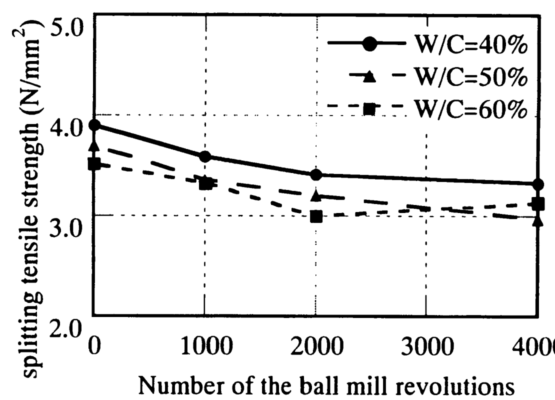

Fig.10 Relations between number of the ball mill revolutions and splitting tensile strength

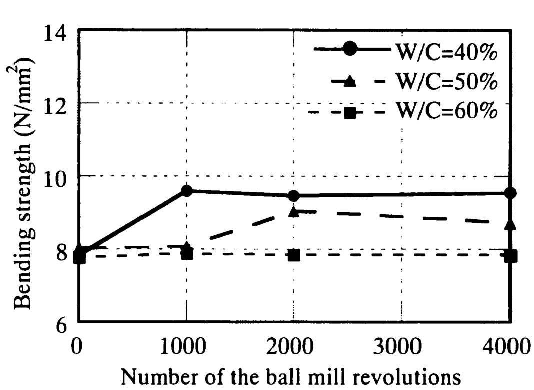

Fig.11 Relations between number of the ball mill revolutions and bending strength

finer. Thus, the addition of revolution draw that hydration products attaching to recycled fine aggregate were removed and its quality was higher and, at the same time, the particle size of recycled fine aggregate was smaller and the recovery percentage were decreased. Increasing percentage of absolute volume is thought to indicate improvement of particle shapes.

These results could suggest that the ball mill refinement make the average density of recycled fine aggregate higher and the average water absorption of it lower, although there was a limit of its effects considering to percentage of the absolute volume, the particle size and the recovery percentage.

(2) Properties of Mortar Used Improved Recycled Fine Aggregate

Figures 7 and 8 show relations between properties of flesh mortar used the improved recycled fine aggregate and number of the ball mill revolutions. The mortar flow value was larger and air content was lower as the number of revolutions increased, although the results were a little scattered. This reason is considered that the particle shape is improved like a sphere by the ball mill. However, the properties of flesh mortar didn't have changes at over 1000 times revolutions because the percentage of absolute volume has little changes.

In Figs. 9, 10 and 11, the results of compressive, splitting tensile and bending strength tests are shown respectively. The compressive and the bending strengths showed an obvious increase when the number of the ball mill revolutions increased, although those strength didn't change over 1000 times revolutions. This tendency became little when the water cement ratio of the mortar was large. Moreover, the splitting tensile strength slightly decreased as the number of revolutions increased.

As the result, properties of flesh and hardened mortar were improved optimistically by 1000 times revolutions of the ball mill refinement, became little effects of this treatment was observed by over 1000 times revolutions refinement.

3. Treatment 2 : Mixing with ordinary fine aggregate

3.1 Test Procedure

An alternative treatment, in which "mixed RF0" made as a mixture of the recycled fine aggregate of ordinary fine aggregate so-called crushed sand, was conducted. Thus, the mortar using the mixed RF0 was tested in same manner described in the previous chapter, and the obtained results were compared with those described in the previous chapter on the mortar using "improved RF0" by the ball mill refinement. Proportions of the mixing RF0 with the crushed sand and qualities of the mixed RF0 are shown in Table 5. Table 6, furthermore, summarized qualities of the improved RF0. Here, the grading of fine aggregates was adjusted to that of the crushed sand due to remove effects of grading.

Table 5 Qualities of the mixed RF0 by treatment 2

Proportion of mixing: Crushed sand(%)	Proportion of mixing: RF0 (%)	Average density (kg/ℓ)	Average water absorption (%)	Percentage of absolute volume (%)
100	0	2.66	1.4	61.9
70	30	2.57	3.3	65.1
55	45	2.53	4.3	64.9
40	60	2.49	5.2	65.1
0	100	2.37	7.8	64.7

Table 6 Qualities of the improved RF0 by treatment 1

Revolution of the ball mill	Average density (kg/ℓ)	Average water absorption (%)	Percentage of absolute volume (%)
1000	2.45	5.5	67.9
2000	2.52	4.5	68.1
4000	2.58	3.4	68.2
Crushed sand	2.66	1.4	61.9

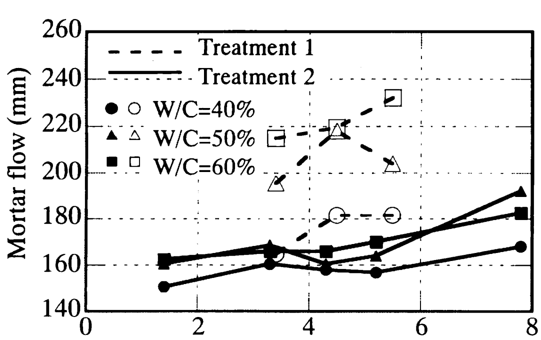

Fig.12 Relations between mortar flow and average water absorption

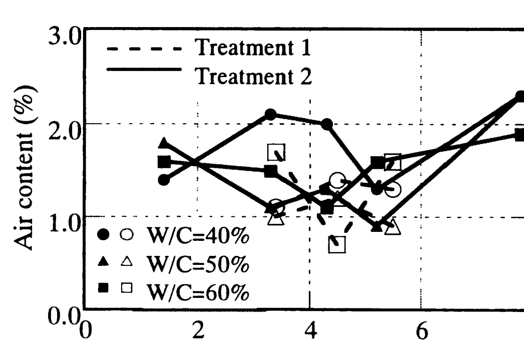

Fig.13 Relations between air content and average water absorption

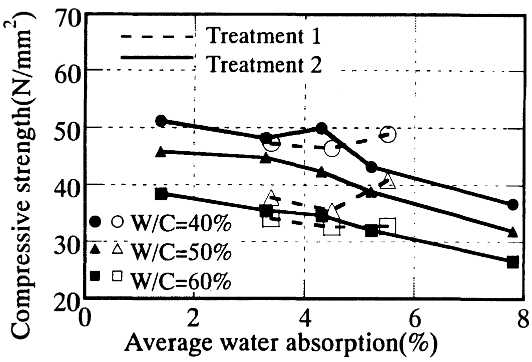

Fig.14 Relations between compressive strength and average water absorption

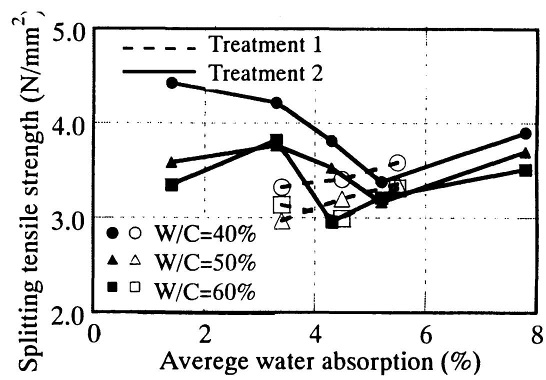

Fig.15 Relations between splitting tensile strength and average water absorption

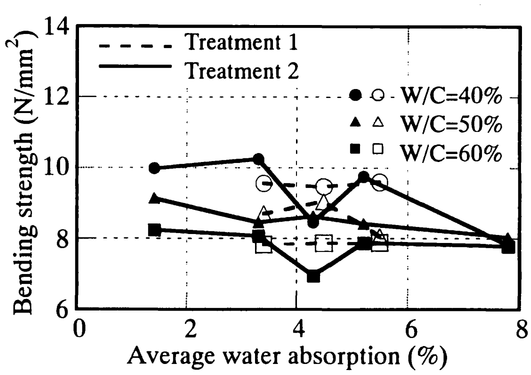

Fig.16 Relations between banding strength and average water absorption

3.2 Results and Discussions

Relations between the average water absorption of fine aggregate and the mortar flow or the air content in flesh mortar were shown in Figs.12 or 13. The mortar flow in case of using the improved RF0 was larger than those in case of using the mixed RF0 in the same average water absorption of the recycled fine aggregate. The recycled fine aggregates with the same water absorption because mostly the same air content of the recycled aggregate mortar. This reason was considered to improve particle shapes of RF0 by treatment 1, because the percentage of absolute volume of the improved RF0 was larger than that of the mixed RF0.

The results of testing about compressive, splitting tensile and bending strength are summarized in Figures 14, 15 and 16. In the results of all strength tests, the mortar strength in case of using the improve RF0 was considered to be mostly as same as that in case of using the mixed RF0. These results suggest that strengths of recycled aggregate mortar are same in spite of difference of aggregate improving processes if the recycled fine aggregates have the same average water absorption. Mortar flow, however, wasn't a fixed rate in this experiment. In condition of the same mortar flow, mortar strength with recycled fine aggregate improved by the ball mill refinement were attributed to be larger than it with recycled fine aggregate mixed with natural sand.

4.Influence of Original Mortar Strengths

4.1 Original Mortar and Recycle Fine Aggregate Produced

To investigate the influence of particle strength of recycled fine aggregate on properties of the recycled aggregate mortar, 3 sorts of original mortar with different compressive strengths, whose water cement ratios were 35, 50 and 60%, were produced with the crushed sand. After had cured in the atmosphere for about 3 months, the original mortar was crushed to produce 3 sorts of the recycled fine aggregates. Original mortar was crashed at 2 times by small size jaw crusher in our laboratory, then particles size ranges of 2.5-0.15mm in those crushed mortar were picked up as 3 sorts of recycle fine aggregates using in this experiment. Mix proportions of original mortar, properties of original

Table 7 Mix proportion of original mortars

W/C(%)	W(kg/m^3)	C(kg/m^3)	S(kg/m^3)
35	299	853	1141
50	312	624	1300
65	320	491	1393

Table 8 Properties of original mortars

W/C of original mortar (%)		35	50	65
Mortar flow (mm)		121	129	126
Air content (%)		3.4	3.1	2.8
Compressive strength (N/mm^2)	28 days (Standard curing)	57.1	41.7	31.6
	97 days (Atmospheric curing)	76.1	58.7	43.1

Note: Original mortars were broken in atmospheric curing at 97days

Table 9 Qualities of recycled fine aggregate made from original mortar

Sort of fine aggregate	Average density (kg/l)	Average water absorption (%)	Percentage of absolute volume (%)	Fineness modulus
35*	2.28	12.3	68.0	2.83
50*	2.26	12.9	69.5	2.96
65*	2.29	11.8	68.2	2.83
Crushed sand	2.66	1.4	61.9	2.72

Note: *W/C (%) of original mortar (see Table 8)

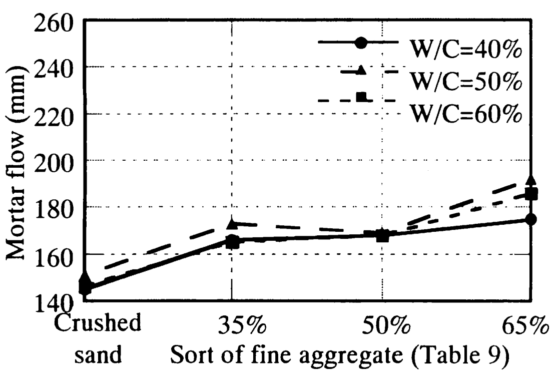

Fig.17 Relations between mortar flow and sort of fine aggregate

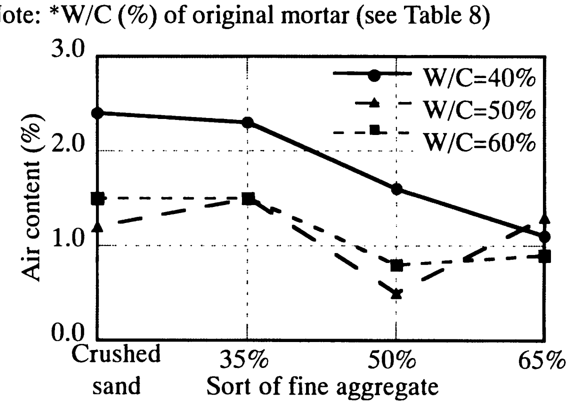

Fig.18 Relations between air content and sort of fine aggregate

mortars and qualities of produced recycled fine aggregate were shown in Tables 7, 8 and 9. And here, those recycle fine aggregates weren't adjusted those grading because those grading were nearly same.

4.2 Results and Discussions

Mortar was made with 3 sorts of the recycled fine aggregate and the crushed sand, then properties of flesh and hardened mortar were tested through air content and mortar flow tests at fresh mortar, and compressive, splitting tensile and bending strength tests at hardened mortar. Figures 17 - 21 show those results. Here, mix proportions of mortars are summarized in Table 4 used at a forgoing experiment.

As the former results, the mortar flow was larger and the air content was slightly smaller in case of the recycled aggregate mortar than that in case of the crushed sand mortar, though in the recycled aggregate mortar, the mortar flow increased and the air content decreased as compressive strength of the original mortar strength increased. Though compressive, splitting tensile and bending strengths were nearly same at same water cement ratio of recycled aggregate mortar in spite of difference of aggregate particle strength. The aggregate particle strength from difference of original mortar strength has little influence on strength of mortar with those recycled fine aggregate.

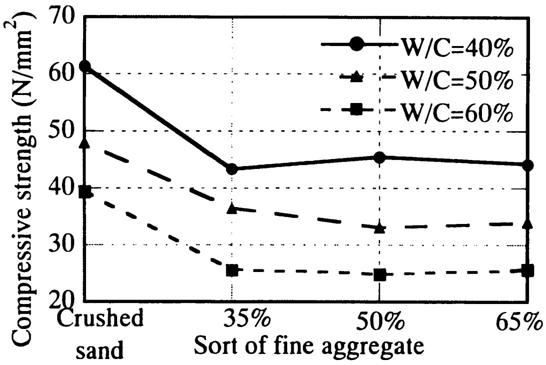

Fig.19 Relations between compressive strength and sort of fine aggregate

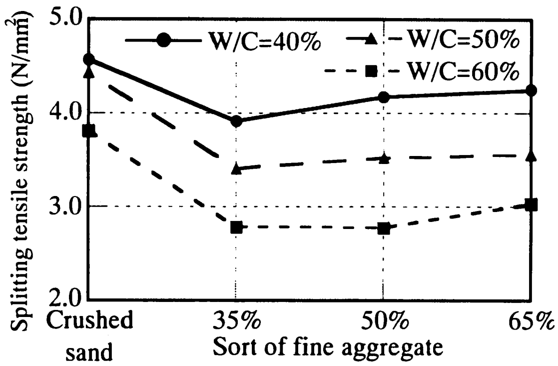

Fig.20 Relations between splitting tensile strength and sort of fine aggregate

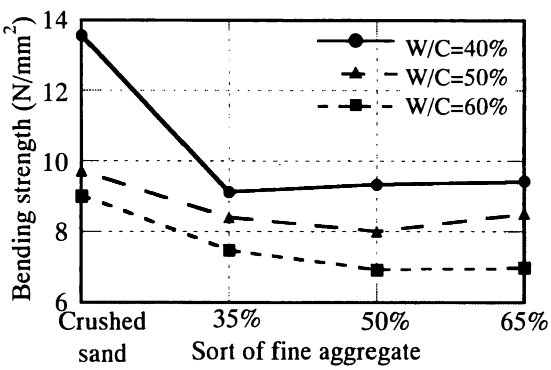

Fig.21 Relations between bending strength and kinds of fine aggregate

5. Conclusions

(1) The ball mill refinement could make the average density of recycled fine aggregate higher and also the average water absorption of it lower. However there was a limitation of the improvement due to reduction both of aggregation size and recovery percentage.

(2) The ball mill refinement could also improve the shape of the aggregate with higher percentage of absolute volume, from which larger mortar flow value resulted.

(3) The compressive, splitting tensile and bending strength of the mortar made of the aggregate improved by the ball mill refinement were as same as those of the mortar made of the aggregate mixed with an ordinary one having same average water absorption.

(4) A little influence of the recycled fine aggregate strength on the recycled aggregate mortar strength could be observed, although it could somewhat affected flesh mortar properties.

References

1) M. Yamada; The Aggregate Recycling from Used Concretes – The Technology, Now and Future, Journal of Japan Institute of Aggregate Technology, No.113, pp.1-8, 1997 (in Japanese).