STUDY OF CONCRETE MODIFICATION EFFECT WITH RECYCLED AGGREGATE TREATED BY CARBONATION

TAKESHI IYODA* AND NOBUHIRO MATSUDA†

* Department of Civil Engineering, associate Professor
Shibaura Insitute of Technology (SIT)
3-7-5, Toyosu, Koto-ku, Tokyo, Japan
e-mail: iyoda@sic.shibaura-it.ac.jp, http://www.db.shibaura-it.ac.jp/~iyoda/

†Tokyo Techno
3343, Onoji-machi, Macida city, Tokyo, Japan
Email: n-matsuda@tokyo-techno.co.jp

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Abstract. Ready-mixed concrete in Japan, if that were not used in the field, concrete that would remain back to the ready-mixed concrete plants is increasing year by year. In Tokyo, in order to reduce the return concrete, it has been taken also measures such as providing a penalty in return concrete, however it can't be easily reduced. Therefore, it is desired the technique for reusing of these concretes. By separating all materials from return concrete, the aggregate is realized a method of utilizing the recovered aggregate. However, in case of that time has elapsed from the mixing on initial ready-mixed concrete, it is difficult to separate them.

In this study, these return concretes are once hardened, it was investigated how to reuse as an aggregate by crushing. However, since the mortar is attached to the surrounding aggregate, the quality of the produced aggregates are not good. Therefore, even lower performance as recycled aggregate, it is difficult to use as aggregate for concrete. However, if it added a high degree of crushing and grinding, in the fact, that energy and cost is also high, the environmental impact is significant. So, in this study, after the rough grinding, a mortar of aggregate was modified by carbonation.

As a result, it was possible to increase the density and water absorption as compared to the original rough milled aggregate. Therefore, to produce a concrete with modified aggregate was significantly improved effect on the concrete strength and the drying shrinkage. By using this technique, it is possible to improve the processing problems of the return concrete. In addition, it is possible to contribute to the reduction of global warming gases by adsorption of carbon dioxide gas. Incidentally, carbon dioxide is considered to be generated from a number of industries and the techniques that lead to environmental reduction technology in society as a whole world.

1 INTRODUCTION

Toward the Construction of environmental impact reduction and recycling-oriented society, it is desired that the promotion of concrete for using the recycled aggregate and also using the recycled aggregate concrete around some construction site [1]. In the future, when considering the maintenance of the existing structures, it is assumed that many structures are updated, and a large amount of concrete mass is expected to occur from many structures. In addition, it has been reported that the large amount of remaining concrete and return concrete were generated in the transportation of ready-mixed concrete in the structure construction site. These demolition and remaining concrete are industrial wastes. Therefore it is necessary to appropriately process. One of the methods, it is conceivable to utilize a recycled aggregate for concrete. This leads to the zero emissions of the entire construction industry also the concrete industry. However, in order to produce recycled aggregate, it spends a high energy and cost, it leads directly to high environment impacts, and it is a need for caution.

Furthermore, in the global problem of global warming, it is very important that reducing the emissions of carbon dioxide as a greenhouse gas. In the cement production on the concrete field, carbon dioxide emissions from energy and non-energy sources is a problem. It is the second of emissions in the manufacturing industry in Japan. Therefore, even in the entire concrete industry, there is a need for new efforts to reduce carbon dioxide emissions.

For this purpose, it is necessary to produce a recycled aggregate at low energy and low-cost as possible. On the other hand, there is important that it is possible to reduce the carbon dioxide emissions during cement production. In this research, focusing on the recycled aggregate production, the recycled aggregate produced at low quality is applying the carbonation technology. As a result we have to understand the property of reforming the recycled aggregate. It was further aimed to research the characteristics of the concrete using these aggregate. In addition, it was discussed reforming the mechanism of recycled aggregate.

2 CARBONATION TECHNOLOGY AND TECHNIQUE

2.1 Carbonation Technology

Calcium hydroxide is known to produce calcium carbonate by adsorbing carbon dioxide. In the concrete, when the carbon dioxide in the atmosphere penetrates into the concrete, the calcium hydroxide of the hydration product in concrete is form the calcium carbonate by adsorbing carbon dioxide. This means that it owns the ability of the concrete to absorb carbon dioxide. This phenomenon is called carbonation, the carbonation in the field of concrete, may not be considered rebar corrosion on reinforced concrete. Rebar in the concrete, normally in an alkaline exist thin oxide film, is in the corrosion difficult state. If carbonated concrete by carbon dioxide, concrete was alkaline to gradually shift to neutral. This is called a neutralization, the thin oxide film by the neutralization progresses is destroyed around the rebar in the concrete and also corroded by the supply of water and oxygen. After then leading to strength decrease of the structure. However, focusing only on concrete, in general, the calcium carbonate produced by the carbonation has a large volume as compared with the calcium hydroxide. Therefore, the resulting calcium carbonate fills the large porosity is also confirmed to be densified. Thus, a large pore is reduced, it is known that improving the strength and the permeability resistance of concrete. So, if we can densify the mortar unit that is attached to the recycled aggregate, it was thought that it might be able overcome the disadvantages in that reduction in strength and low permeability resistance of recycled aggregate concrete.

2.2 Improving Recycled Aggregate

In Japan, recycled aggregate which is depending on their quality, H and M and L classification of its property and concrete provisions have been made on JIS A 5021, JIS A in 5308 Annex and JIS A 5022, 5023. [2-5] The index is made by absolute dry density and water absorption. High-quality recycled aggregate H can be used as concrete aggregate. However, it needs the high cost and a lot of energy to manufacture. Meanwhile, the reproduction in the aggregate M and L, in general it is difficult to use as a concrete aggregate, there is only available in the precursor concrete of floor leveling concrete or underground. However the cost and energy is small in manufacturing for these aggregate. In the future, in order to spread the recycled aggregate is considered that it is necessary to manufacture by low cost and energy of high quality recycled aggregates. Therefore a low-quality recycled aggregates prepared at low cost and low energy tried to be improved using carbonation technology as introduced above [6].

Table 1 List of recycled aggregate using in this research

			Manufacturing		Concrete
		class	crash	Ground	
Corse Agg.	N	Normal			Crash
	MA	M	○	○	Dismantling
	MB		○	○	Dismantling*
	MC		○	○	Dismantling*
	MD		○	○	Dismantling*
	LA	L	○	-	Dismantling
	LB		○	-	Dismantling
	LC		○	-	Dismantling
	LD		○	-	Dismantling
	OA	Out	○	-	Returning
	OB		○	-	Returning
Fine	NS	Normal			Crash
	MS	M			Dismantling*
	LS	L			Dismantling
	OS	Out			Returning

* including a part of returning concrete

In this research, the recycled aggregate was carbonated for 7 days on the accelerated carbonation device (temperature 20 ℃, relative humidity of 60%, concentration of carbon dioxide at 5%). The samples are stirred once every two days, carbon dioxide is to be able to fill absorbed throughout the aggregate. It is shown in Table 1 on the recycled aggregate that used in this study. In addition, it shows a list of physical properties of the improved before and after of recycled aggregate in Table 2. Aggregate was used coarse aggregate M and L produced from dismantled concrete and under L as non-standard (O) produced from the return concrete of construction site. It showed the physical properties of recycled aggregates on the improved before and after for carbonation technology in Figure 1. In all of the aggregate have improved density and water absorption, it is understood that some aggregates are classes up. Thus was possible improvement of physical properties by carbonation technology. Figure 2 shows the relationship between the amount of mortar ratio and water absorption of recycled aggregate. Here amount of mortar ratio, including directly measured and calculated from

Table 2 Physical properties on recycled aggregate before and after improving by carbonation

			Before improving						After improving (absorbed CO_2)				
		class	Drying density (g/cm^3)	Water absorption (%)	Value of crashing	Mortar content ratio (%)	Porosity (vol%)		Drying density (g/cm^3)	Water absorption (%)	Value of crashing	Mortar content ratio (%)	Porosity (vol%)
corse	N	Normal			-	-							
corse	MA	M	2.50	3.06	7.9	15.10	8.1	CMA	2.52	2.63	6.0	15.13	7.5
corse	MB	M	2.51	3.01	7.8	19.69	7.4	CMB	2.53	2.27	6.4	18.02	5.4
corse	MC	M	2.44	3.94	8.7	28.51	9.6	CMC	2.46	3.38	7.7	28.53	8.6
corse	MD	M	2.43	3.47	7.9	21.7	8.0	CMD	2.44	3.38	8.0	22.0	8.2
corse	LA	L	2.32	5.69	11.4	40.95	12.8	CLA	2.3	4.97	11.0	42.94	11.6
corse	LB	L	2.35	5.66	13.6	40.82	12.9	CLB	2.4	4.61	13.2	40.97	10.6
corse	LC	L	2.24	6.13	13.9	42.9	13.9	CLC	2.28	5.56	11.6	34.7	12.7
corse	LD	L	2.26	6.82	18.3	57.05	15.5	CLD	2.27	6.18	17.8	57.00	14.2
corse	OA	Out	2.21	7.44	17.3	53.94	16.7	COA	2.3	5.88	16.4	56.31	12.8
corse	OB	Out	2.00	10.79	18.8	60.2	21.3	COB	2.09	7.53	19.0	60.9	15.8
fine	NS	Normal			-	-							
fine	MS	M	2.34	4.80	8.4	-	11.3	CMS	2.35	4.68	6.1	-	11.0
fine	LS	L	1.94	12.92	12.8	-	25.1	CLS	1.97	12.18	11.7	-	24.0
fine	OS	Out	1.92	14.57	16.1	-	28.0	COS	1.95	12.87	13.6	-	25.1

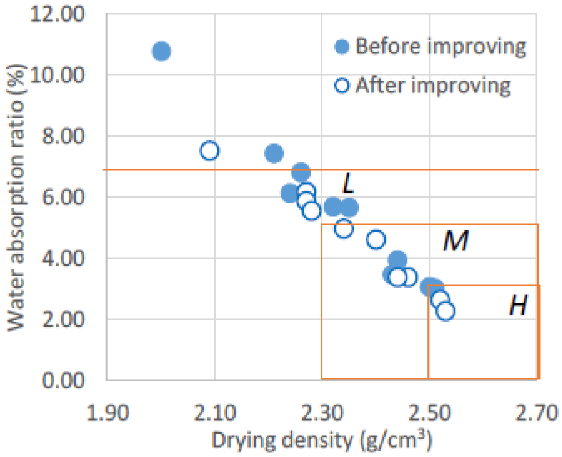

Figure 1 changing physical properties

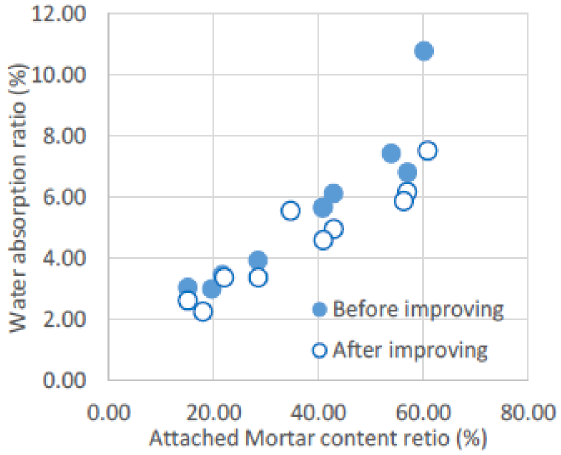

Figure 2 Mortar content and water absorption

crushing value as a reference [7]. The amount of mortar ratio is not changed by accelerated carbonation, it can be seen that only the water absorption rate is improved.

3 EFFECT OF IMPROVING RECYCLED AGGREGATE APPLIED CONCRETE

3.1 Using material, mix proportions and testing methods

The concrete was produced using improving recycled aggregate. It was performed compression strength, splitting strength test and the length change test in the manufactured concrete. Concrete was using a blast furnace slag cement type B (replacement BFS ratio is 50%). Mix proportion of concrete is water cement ratio 50%, and s/a 50%, unit of water 170 kg/m^3 was constant. For the compressive strength, it produced the concrete with all recycled aggregate. It should be noted that fine aggregate was using a crushed sand. On the other hand, we were using L and the aggregate of non-standard for the length change as drying shrinkage test. The reason is because the improving effect was observed in the compressive strength test. The mix proportion of concrete prepared are shown in Table 3. In addition it was also shown the measurement results of the slump, air content and compressive strength of fresh concrete in this table. Fresh concrete in all concrete was almost same properties.

Table 3 List of the concrete for drying shrinkage test

	absorbed CO_2	corse	fine	Slump (cm)	Air (%)	Compressive strength (N/mm^2)
NN	—	N	NS	11.0	5.9	28.9
LAN	None	LA	NS	8.0	5.0	30.6
LBN		LB	NS	11.5	5.3	29.4
LCN		LC	NS	9.5	4.5	27.1
LCL		LC	LS	12.0	5.5	21.3
OAN		OA	NS	12.0	5.4	27.9
OBO		OB	OS	10.5	5.9	22.0
CLAN	Yes	CLA	NS	11.5	5.5	27.2
CLBN		CLB	NS	12.0	5.7	28.4
CLCN		CLC	NS	9.0	5.0	25.6
CLCCL		CLC	CLS	10.0	4.8	22.9
COAN		COA	NS	9.0	3.5	28.5
COBCO		COB	COS	7.0	6.5	20.1

The test method was carried out to determine the physical properties due to improving recycled aggregate. Compressive strength [8] and splitting tensile strength test [9] is conforming to JIS (Japanese Industrial Standard). Test specimen is cylinder specimen of φ100 × 200mm. Curing is carried out on the 28 day to 20 ℃ water curing, the strength test was carried out in three specimens. It was calculated strength than its average value.

Drying shrinkage test of the concrete was performed with JIS A 1129-3. It was de-frame in 1 day after the casting of the concrete, curing was performed 7 days in water at 20 ℃. Then, it was placed at temperature 20 ℃ and humidity 60% RH environment. The length change was measured in 1,2,4,8 and 13 weeks from the start of the drying.

3.2 Results of strength test

Figure 3 and 4 show the results of compressive strength and splitting tensile strength tests. Strength properties of concrete using improving recycled aggregate, it is not shown greatly improved. However it can be seen that strength of the improving recycled aggregate concrete is same or a little bit high compared with originated recycled aggregate concrete. Especially improving effect of strength is seen remarkably by using the aggregates of L and non-standard (O). In addition, it seems relatively high improving effect in splitting tensile strength.

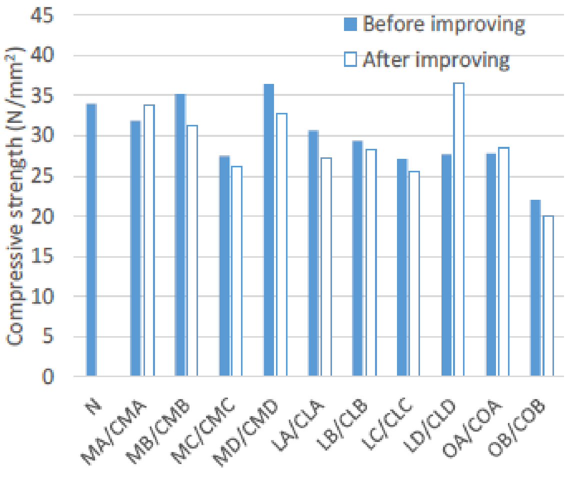

Figure 3 Results of compressive strength

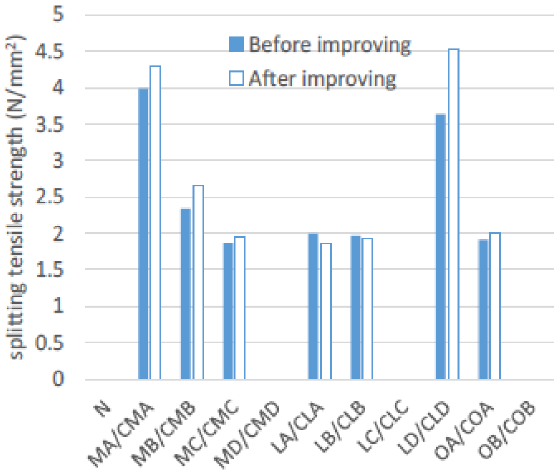

Figure 4 Results of splitting tensile strength

3.3 Results of drying shrinkage test

Figure 5 is the result of length change test (Drying shrinkage) in the drying age at 8 weeks (56 days). Drying shrinkage rate is small at all the mix proportions by improving recycled aggregate concrete compared with originated recycled aggregate concrete. From this result, recycled aggregate by adsorption of carbon dioxide is improving, it can be said that the drying shrinkage rate also decreases. Further, the drying shrinkage ratio of LCL concrete using the fine recycled aggregate is large as compared to the LCN concrete using normal fine aggregate. Drying shrinkage rate of concrete using recycled fine and coarse aggregate are tended to be larger than that of concrete using only recycled coarse aggregate. This is similar to what has been reported in previous literature. Also it was observed that the improving effect of the carbon dioxide adsorption in concrete using recycled fine aggregate. The improving effect was observed on COAN and COBCO concrete that was the improving recycled aggregate of non-standard (O). These recycled aggregate is used as a return concrete. Therefore, it said recycled aggregate which can be expected improving effect by the carbon dioxide adsorbed is an aggregate produced from the concrete without over time from the production, compared with the recycled aggregate from the long shared concrete.

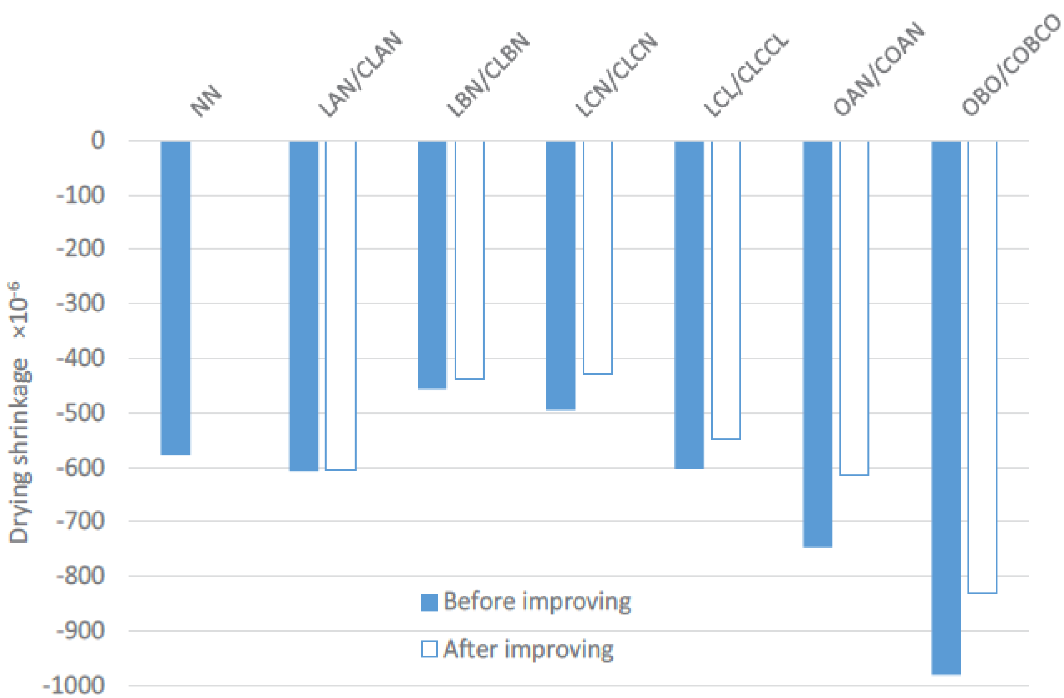

Figure 5 Results of drying shrinkage at 56 days

4 MECHANISM OF DRYING SHRINKAGE REDUCTION ON IMPROVING RECYCLED AGGREGATE

Here, particularly it consider a mechanism of improving effect of aggregate properties and reduction of the drying shrinkage using the recycled aggregate as a return concrete. Therefore,

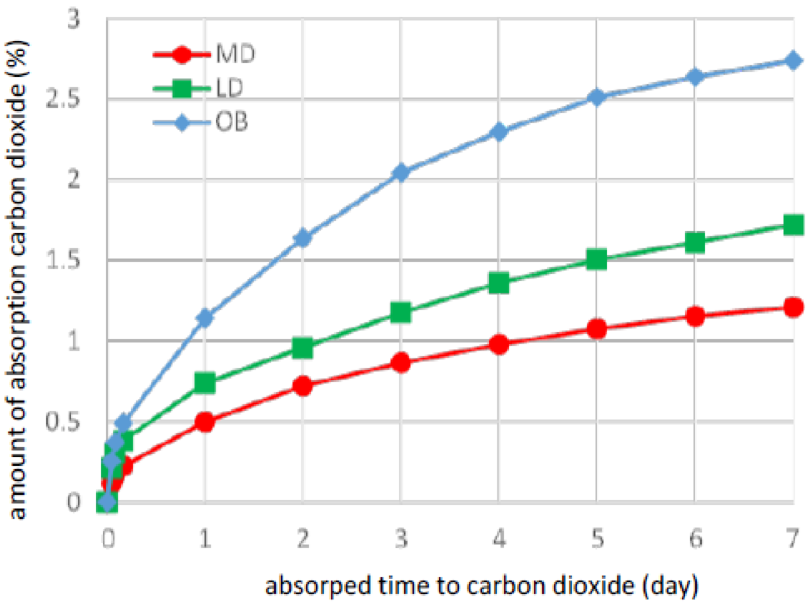

Figure 6 Results of amount of adsorption carbon dioxide

the results of the measurement of the amount of adsorption carbon dioxide on recycled aggregate was shown in Figure 6. The amount of carbon dioxide adsorption is much as a low-quality aggregate and concrete as short time from production.

Next it is shown in Figure 7 the results of the pore volume of the recycled aggregate is measured by the Archimedes method. Obviously porosity of improving recycled aggregate has decreased in all of the original recycle aggregate, it is densified. Therefore, the observation of the products of the pore using a SEM, production of calcium carbonate was confirmed as shown in Figure 8. This densification of the attached mortar on recycled aggregate due to carbonation is the effect to improving physical properties of aggregate and drying shrinkage reduction of concrete.

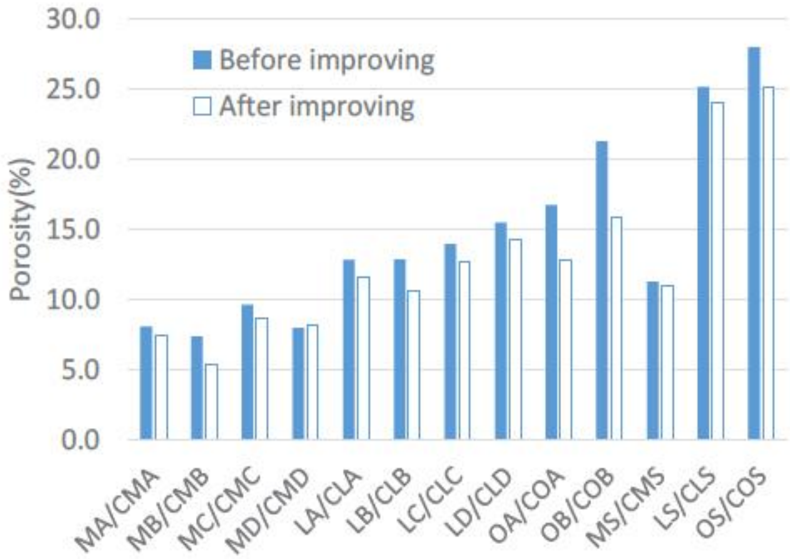

Figure 7 Results of porosity

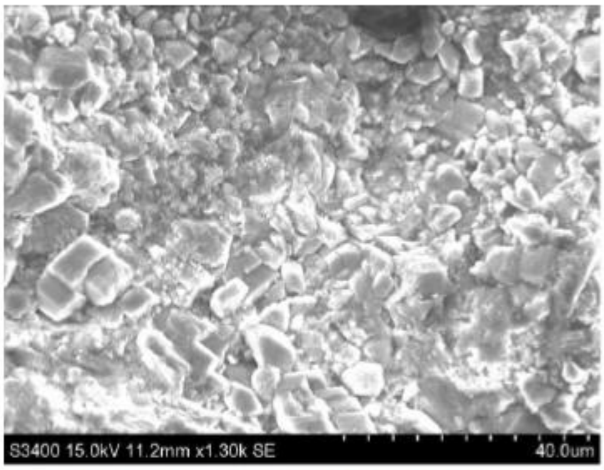

Figure 8 Products after improving in pore (calcium carbonate)

5 FUTURE WORKS OF IMPROVING RECYCLED AGGREGATE

In this way it is improving low-quality recycled aggregate by carbonation, it could suggest the possibility that can be applied to concrete. The measures to realize this system is considered as follows.

(1) Return concrete (which returning concrete from construction site produced by the ready-mixed concrete plants) and the remaining concrete is expanded in the yard, and to be solidify.

(2) It is crushed easily to adjust to the aggregate particle size.

(3) Production of low-quality recycled aggregate will be transported to the plant that are burning fuel in close proximity to the ready-mixed concrete plants (for example, cement plants, biomass energy plant).

(4) Using carbon dioxide from the plant of burning fuel, recycled aggregate is adsorbing the carbon dioxide.

(5) The improving recycled aggregate is transported to ready-mixed concrete plant again, and it will be used to produce concrete replaced with normal aggregate.

By stepping on this process, it is considered that it also can contribute to the reduction of carbon dioxide emission in a plant of burning fuel. As a result we think that also lead to contributing to a recycling society. In the future, it is considered to determine the replacing ratio of recycled aggregate with ordinary aggregate for having required performances.

6 CONCLUSIONS

The summarized results obtained in this research as follows.

- The dry density increases and water absorption was small on recycled coarse aggregate and recycled fine aggregate using carbonation technology such as adsorption of carbon dioxide
- Strength properties of concrete using the improving recycled aggregate was equivalent or improved the original recycled aggregate concrete.
- The drying shrinkage rate is improvement due to the adsorption of carbon dioxide on recycled aggregate concrete.
- Adsorption ratio of carbon dioxide became larger as having a high attached mortar ratio. In addition, the aggregate for adsorption ratio of carbon dioxide is large, attached mortar part had become dense.
- By measuring the adsorption ratio of carbon dioxide to be screened is recycled aggregate of drying shrinkage reducing effect. To adjust the required performance of the concrete, it is considered that there is a possibility for contributing to the the low-quality recycled aggregates concrete using improvement by adsorption of carbon dioxide.
- If forced carbonation using exhaust gas such as a cement plant, leading to a reduction in emissions of carbon dioxide from the factory. And producing the low-quality recycled aggregates from the return concrete is low cost and low energy thereby reducing the environmental impact. Furthermore, for improving recycled aggregate easily by using the proposed carbonated techniques in this research, it was suggested that lead to concrete production to reduce the environmental impact.

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