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A Few Remarks on the Alkali-aggregate Reaction of Recycled-glass Concrete

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The authors have proposed that waste glass, which is crushed to pieces, can be used as a concrete aggregate. At the present time, recycled-glass concrete is used for sidewalk concrete blocks and pavement as glass is ornamental. However, in cases where recycled-glass concrete is used for structural concrete, strength and durability are required as structural concrete is exposed to the weather. Glass that is used generally is a mixture of SiO_2, Na_2O and CaO. SiO_2 is the most likely cause of alkali-aggregate reaction when waste glass was used for concrete aggregate. In this study, an alkali-aggregate reaction test that is one of the important tests related to durability of aggregate was carried out for discussion of utilization of waste glass for concrete aggregate. From the results of the tests, it is found that glass is a reactive aggregate. The pessimum proportion of glass is about 75 %. Then the cases of using fly ash, blast furnace slag and artificial zeolite for admixture materials were also examined for the purpose of prevention of alkali-aggregate reaction. From the results of the test, it was found that using them is an effective way to prevent alkali-aggregate reaction. The compressive strength in the cases of using admixture materials is larger than that without admixture materials.

Introduction

In general, it is said that using waste glass instead of new glass products is difficult for economic reasons as waste glass is a mixed variety of glass. Thus, waste glass from general home use is junked without recycling, so it increases remarkably. On the other hand, obtaining land for garbage disposal is becoming difficult for environmental reasons. With these points as background, it is important to investigate waste glass recycling.

The authors have proposed that waste glass, which is crushed to pieces, can be used as a concrete aggregate [1]. At the present time, recycled glass concrete is used for sidewalk concrete blocks and pavement for the reason that glass is ornamental. However, in cases where recycled-glass concrete is used for structural concrete, strength and durability are required as structural concrete is exposed to the weather.

Glass that is used generally is a mixture of SiO_2, Na_2O and CaO. SiO_2 is the most likely cause of alkali-aggregate reaction when waste glass was used for concrete aggregate.

In this study, an alkali-aggregate reaction test that is one of the important tests related to durability of aggregate was carried for discussion of utilization of waste glass for concrete aggregate. Then the cases of using fly ash, blast furnace slag and artificial zeolite for admixture materials were also examined for the purpose of prevention of alkali-aggregate reaction.

Physical Properties of Waste Glass

The waste glass from general home use was crushed to pieces for fine aggregate. Table 1 shows the physical properties of the glass and the sea sand for fine aggregate. The glass meets the specified values of the specific gravity in both saturated surface-dry condition and absolute dry condition, percentage of water absorption and amount of material passing standard sieve 74 μm.

Test for Alkali-Aggregate Reaction

Testing Method

Glass that is used generally is a mixture of SiO_2, Na_2O and CaO. SiO_2 is the most likely cause of alkali-aggregate

Table 1 Physical properties of the glass using the tests.

	specific gravity in saturated surface-dry condition	specific gravity in absolute dry condition	percentage of water absorption (%)	mass of unit volume (kg/l)	percentage of absolute volume (%)	amount of material passing standard sieve 74μm (%)
glass	2.51	2.51	0.00	1.39	55.40	0.07
sea sand	2.59	2.56	1.36	1.59	62.10	2.50
specified value	≧2.50	≧2.50	≦3.00	–	–	≦3.0 or 5.0

Table 2 Mix proportion of the specimen using the tests.

	Unit content (kg/m^3)					
	W/C (%)	W		Cement, C	Fine aggregate, S	
		Water	1mol/l-NaOH		Sea sand	Glass
G =100%	50	184	116	600	0	1350
G = 75%					338	1013
G = 50%					675	675
G = 25%					1013	338
G = 0%					1350	0

Table 3 Mix proportion of the specimen using the tests in case of using admixture materials.

Admixture material	Ratio of Admixture material to cement (%)	Unit content (kg/cm^3)						
		W/C (%)	W		C		Fine aggregate, S	
			Water	1mol/l-NaOH	Cement	Admixture material	Sea sand	Glass
—	0	50	184	116	600	0	0	1350
fly ash	10				540	60		
	20				480	120		
	30				420	180		
blast furnace slag	20				480	120		
	40				360	240		
	60				240	360		
artificial zeolite	5				570	30		
	10				540	60		
	20				480	120		

reaction when waste glass was used for concrete aggregate. In this study, the alkali-aggregate reaction test that is one of the important tests related to durability of aggregate was carried out.

The tests were carried out according to JIS A 5308. The mortar bar specimen was 40x40x160 mm for measuring the expansion of mortar due to alkali-silica reaction. The specimens were cared for maintaining a temperature of 40°C and a humidity of 95 %. The test ages of the specimens were 1, 2, 4, 8 weeks, 3, 4, 5 and 6 months. The mix proportions of the specimens are shown in Table 2.

Then the cases of using fly ash, blast furnace slag and artificial zeolite for admixture material were also examined for the purpose of reduction of the expansion of the mortars due to alkali-silica reaction. Table 3 shows the mix proportions in the case of using admixture materials.

Results and Discussions

Fig. 1 shows the relationship between the age under accelerated curing and the expansion of the mortar bar due to alkali-silica reaction. The expansions which the ratio of glass to aggregate by weight is 50 %, 75 % and 100 % is 0.1 % or greater after 6 months. From this fact, it is found that the glass is the reactive aggregate. In the case where the ratio of glass to aggregate by weight is 75 %, the expansion of the specimen is about 0.4 % and greatest of all specimens. It is supposed that the pessimum proportion of the glass is about 75 %.

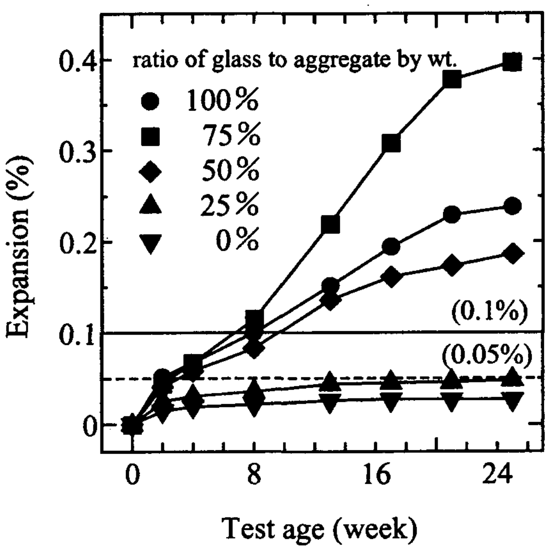
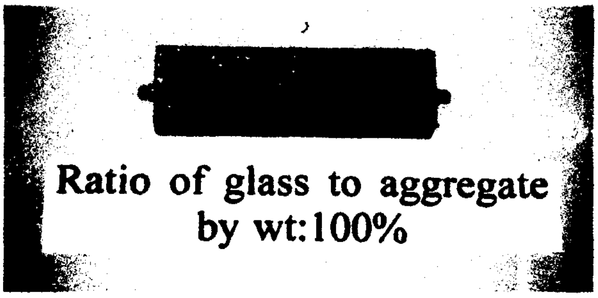
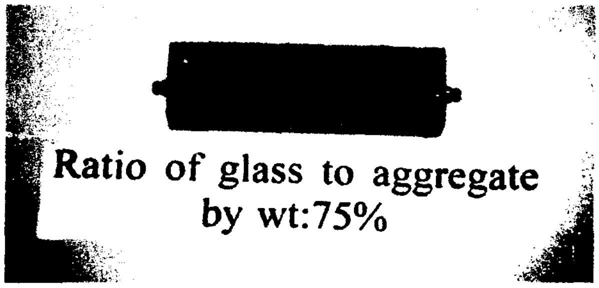


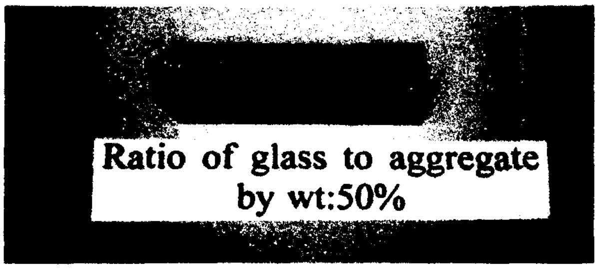
Fig. 1 Relationship between the age under accelerated curing and the expansion of the mortar bar due to alkali-silica reaction.



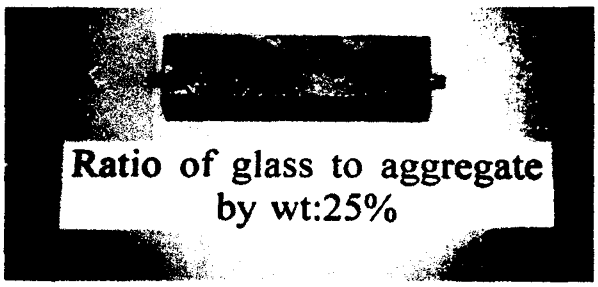
(a) ratio of glass to aggregate by weight: 100%



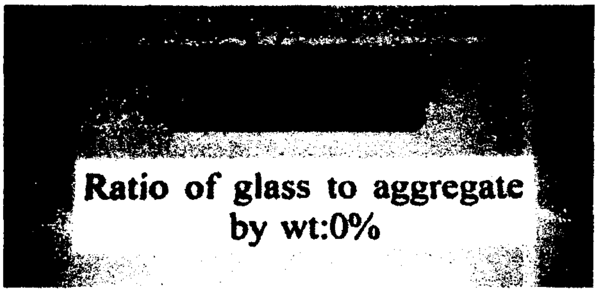
(b) ratio of glass to aggregate by weight: 75%



(c) ratio of glass to aggregate by weight: 50%

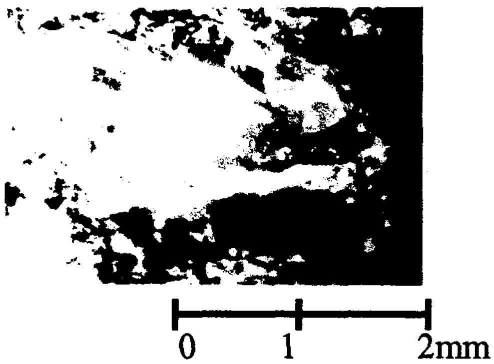


(d) ratio of glass to aggregate by weight: 25%

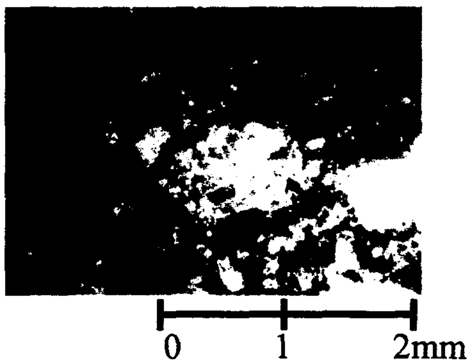


(e) ratio of glass to aggregate by weight: 0%

Fig.2 External view of the mortar bars after 6 months.

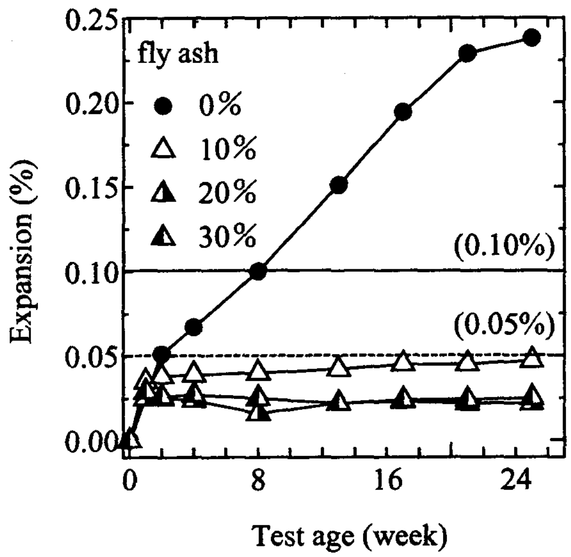


(a) ratio of glass to aggregate by weight: 75%

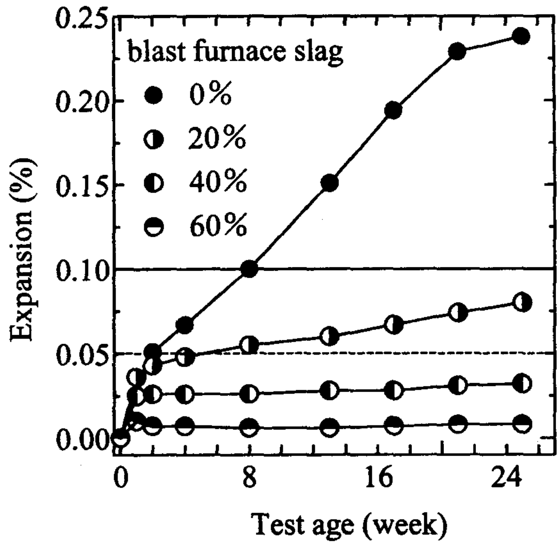


(b) ratio of glass to aggregate by weight: 0%

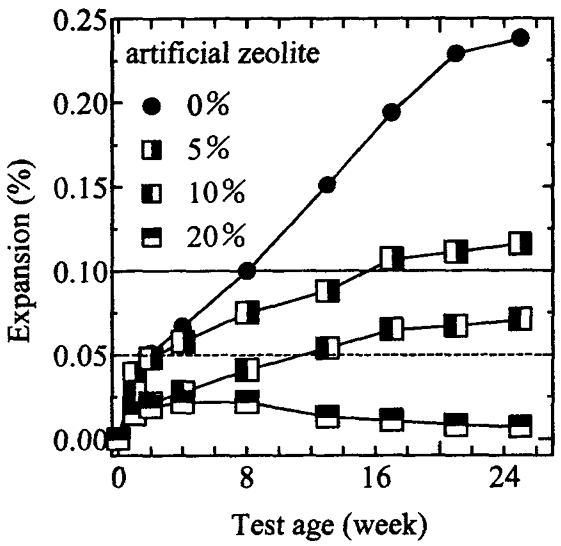
Fig.3 Enlargement of the specimen's surface after 6 months.



(a) fly ash



(b) blast furnace slag



(c) artificial zeolite

Fig. 4 Relationship between the age and the expansion of mortar in the cases of using fly ash, furnace slag and Na type artificial zeolite for admixture materials for the purpose of prevention of the expansion due to alkali-silica reaction.

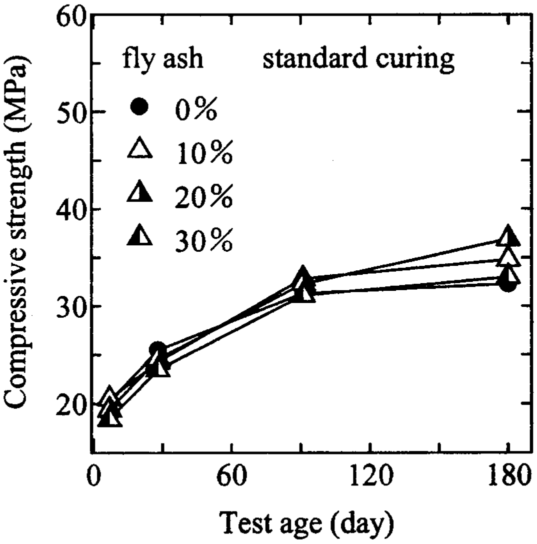
The external view of the mortar bars after 6 months is shown in Fig.2. In cases where the ratio of glass to aggregate by weight is 50 %, 75 % and 100 %, cracks occurred in the specimens. Fig.3 shows the enlargement of the specimen's surface. The gel filling empty spaces can be seen.

Fig.4 shows the relationship between the age and the expansion of mortar in the cases of using fly ash, furnace slag and Na type artificial zeolite for admixture materials for the purpose of prevention of the expansion due to alkali-silica reaction. In the cases of using fly ash, and blast furnace slag, the expansion of all specimens is less than 0.1 % after 6 months. The expansion of the specimens using artificial zeolite is also less than 0.1 % after 6 months except in the case of using 5 %.

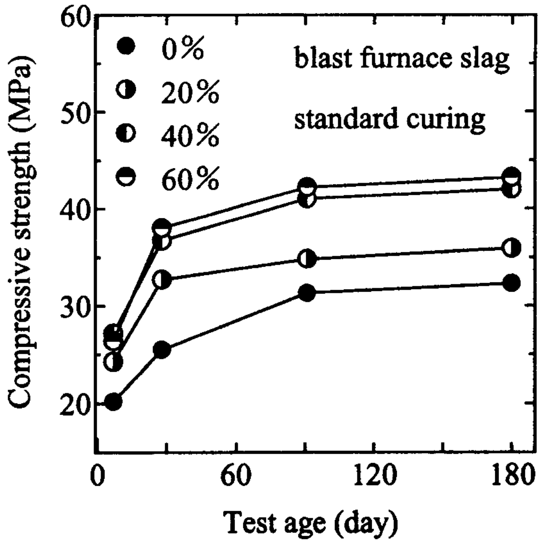
From the results of the tests, it was found that using fly ash, blast furnace slag and artificial zeolite for admixture materials is one of the effective ways to prevent alkali-silica reaction.

Strength Test

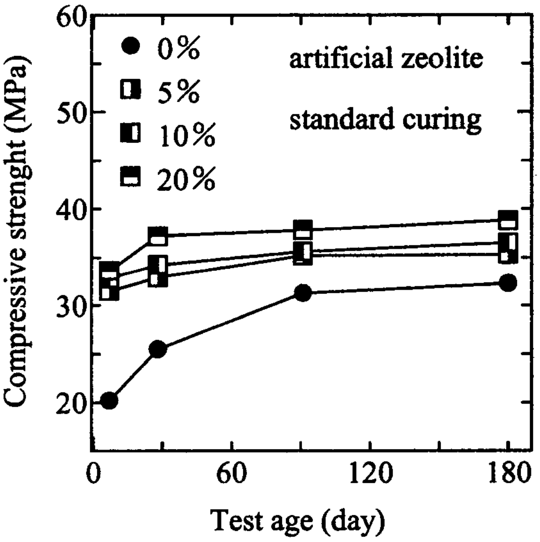
The compressive strength of mortar using fly ash, blast furnace slag and artificial zeolite for admixture materials was investigated after standard curing. The test ages of the specimens were 7, 28, 91 and 180 days. The results of the test were shown in Fig.5. Fig.6 shows the change of compressive strength in the case of using admixture materials. The accelerated curing was carried out. The compressive strength of the specimens using admixture materials is larger than that without admixture materials.



(a) fly ash



(b) blast furnace slag



(c) artificial zeolite

Fig. 5 Compressive strength of mortar using fly ash, blast furnace slag and artificial zeolite for admixture materials under standard curing.

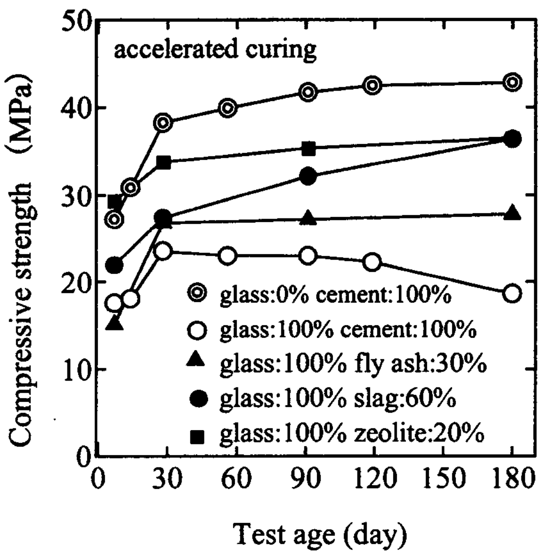


Fig.6 Change of compressive strength in the case of using admixture materials under accelerated curing.

Conclusions

The main results obtained in this study are as follows:

1. From the results of the tests, it is found that glass is a reactive aggregate. The pessimum proportion of glass is about 75 %.

2. Using fly ash, blast furnace slag and artificial zeolite for admixture materials is an effective way to prevent alkali-silica reaction.

3. The compressive strength in the cases of using admixture materials is larger than that without admixture materials.

References

[1] Inada, Y., Kinoshita, N., Tanaka, G. & Matsushita, S. 1999. Thermal Characteristics of Recycled - glass Concrete. Proc. of Fifth Int. Symp. on East Asian Recycling Technology. pp.135-138.