MINIMIZING OF ALKALI-AGGREGATE REACTION IN CONCRETE

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Based on the investigations on Alkali-Aggregate Reaction (AAR) carried out in General Building Research Corporation (GBRC) since 1983, a minimizing method of AAR in concrete by utilizing both rapid methods for the evaluation of alkali-reactivity of aggregates and for the identification of susceptibility to AAR in concrete is proposed.

INTRODUCTION

Concerning AAR, since 1983, GBRC has carried out lots of testing of aggregates, field surveys of deteriorating concrete structures and investigations on the development of new rapid methods for identification of not only alkali-reactivity of aggregates, but also susceptibility to AAR in concrete. As a result of the investigations, the authors propose a new method for minimizing AAR in concrete by utilizing rapid methods.

IDENTIFICATION OF ALKALI-REACTIVITY OF AGGREGATE

Alkali-reactivity of river-dredged aggregates

Typical test results are shown in Fig. 1, which indicates both results of JIS Chemical test and JIS Mortar-bar test on river-dredged aggregates, both coarse and fine aggregates from several dredging points of five rivers in some district in Japan [1]. According to the results, the following conclusions can be drawn.

1) Alkali-reactivity of each aggregate dredging up from the same river varies from dredging site to site, and depends on whether it is fine or coarse aggregate.
2) Innocuous aggregates identified by JIS Chemical test are not necessarily identified innocuous by JIS Mortar-bar test.

Rapid test (JIS A 1804)

JIS A 1804 ; Methods of test for production control of concrete—Method of rapid test for identification of the alkali reactivity of aggregates, was officially announced on March 1st, 1992. TABLE 1 and TABLE 2 show the list of aggregate samples taken from all over Japan and the comparison of test results of the samples by JIS Chemical method, JIS Mortar-bar method and JIS Rapid method, respectively. Fig. 2 shows pessimum behaviours of some aggregates, which are identified innocuous by JIS Mortar-bar method and deleterious by both JIS Chemical method and JIS Rapid method. The flow of JIS Rapid test is described in Fig. 3.

IDENTIFICATION OF SUSCEPTIBILITY TO AAR IN CONCRETE

Expansion test (JASS 5NT-603, JCI AAR-3)

Long-term expansion test methods of JASS 5NT-603 and JCI AAR-3 were standardized in 1991 as a test for concrete structures in nuclear power stations by Architectural Institute of Japan and as a test for general concrete structures by Japan Concrete Institute, respectively.

Rapid test

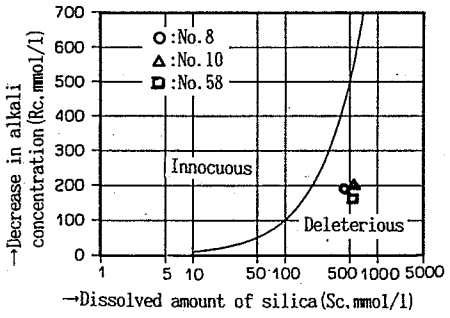
The Rapid test shown in Fig. 4 was tentatively determined in 1991 in the committee held by National Ready Mixed Concrete Industry Association [2]. Fig. 5 shows the relationships of 207 concrete mixes between the results by JCI AAR-3 and by the Rapid test [2, 3].

MINIMIZING PROCEDURE FOR AAR IN CONCRETE

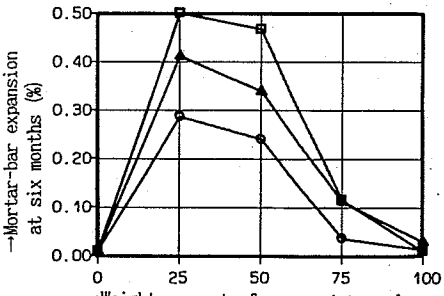
According to the results mentioned above, procedures for minimizing AAR in concrete are recommended as shown in Fig. 6.

REFERENCES

1. Saitoh, H., Tamura, H., Fukushima, S., and Matsunami, Y., 1990, Proc. of JCI, Vol.12, No.1, 757.
2. Kishitani, K., Kobayashi, M., and Tamura, H., 1992, Proc. of 9th Int. Conf. on AAR.
3. Tamura, H., Takahashi, T., and Ohashi, M., 1992, Proc. of Int. Conf. of Advances in Concrete Technology, Athens, Greece.



(a) Test result by JIS Chemical method



(b) Relationships between weight percent of aggregate sample in total aggregate (innocuous aggregate + aggregate sample) and mortar-bar expansion at six months

Figure 2 Pessimum behaviour of aggregate samples which are evaluated deleterious and innocuous by JIS Chemical method and JIS Mortar-bar method, respectively

TABLE 1 — Rock type and geological age of aggregate samples

Sample No.	Rock Type	Geological Age	Sample No.	Rock Type	Geological Age	Sample No.	Rock Type	Geological Age
1	Dacite	Neogene	21	Andesite	Quaternary	41	Slate	Permian
2	Pyroxeneandesite	Neogene	22	Schalstein	Quaternary	42	Porphyry	Cretaceous
3	Quartzdiorite	Neogene	23	Sandstone	Cretaceous	43	Sandstone	Permian
4	Andesite	Neogene	24	Gneiss	Cretaceous	44	Sandstone	Permian
5	Andesite	Neogene	25	Quartz schist	Cretaceous	45	Andesite	Neogene
6	Siliceous slate + Porphyrite	Triassic to Jurassic	26	Basalt	Permian	46	Sandstone	Cretaceous
			27	Diabase	Permian	47	Diabase	Permian
7	Siliceous slate	Permian	28	Gneiss	Jurassic to Early Cretaceous	48	Sandstone	Cretaceous
8	Lamprophyre	Neogene				49	Granite	Cretaceous
9	Basalt	Neogene	29	Sandstone + Siltstone	Neogene	50	Serpentinite	Permian
10	Andesite	Neogene				51	Crystalline schist	Permian
11	Porphyrite	Late Mesozoic and earlier	30	Diorite	Permian	52	Greenschist	Latest Permian to Early Triassic
12	Crystalline schist		31	Peridotite	Permian			
13	Sandstone hornfels	Cretaceous	32	Andesite	Neogene	53	Pyroxene andesite	Quaternary
14	Hornfels	Quaternary	33	Liparite	Neogene	54	Gabbro	Neogene
15	Sandstone	Neogene	34	Sandstone	Permian	55	Andesite	Neogene
16	Sandstone	Quaternary	35	Sandstone	Permian	56	Sandstone	Cretaceous
17	Sandstone	Cretaceous	36	Quartz porphyry	Cretaceous	57	Andesite	Palaeogene
18	Sandstone + Siltstone	Quaternary	37	Rhyolite	Cretaceous	58	Andesite	Quaternary
			38	Trachyte	Permian	59	Limestone	Permian
19	Sandstone	Cretaceous	39	Dacite	Neogene	—	—	—
20	Andesite	Neogene	40	Andesite	Palaeogene	—	—	—

TABLE 2 — Relationships among three kinds of test results; JIS Chemical method, JIS Mortar-bar method and JIS Rapid method

Sample No.	JIS Rapid method						JIS Chemical method			JIS Mortar-bar method						
	Ultrasonic pulse velocity ratio (%) and judgment *		Relative dynamic modulus of elasticity (%) and judgment *		Length change (%) and judgment *		Sc (mmol/ℓ)	Rc (mmol/ℓ)	Judgment *	Expansion (%) 2weeks	4weeks	8weeks	3months	4months	6months	Judgment *
1	97	○	89	○	0.03	○	42	179	○	0.004	0.014	0.021	0.027	0.034	0.045	○
2	96	○	87	○	0.04	○	79	195	○	0.005	0.010	0.015	0.021	0.025	0.032	○
3	98	○	91	○	0.03	○	20	34	○	0.016	0.018	0.022	0.027	0.032	0.040	○
4	98	○	90	○	0.03	○	30	130	○	0.001	0.002	0.003	0.004	0.005	0.007	○
5	98	○	93	○	0.01	○	15	193	○	0.001	0.002	0.002	0.003	0.003	0.003	○
6	98	○	92	○	0.03	○	20	209	○	0.003	0.015	0.018	0.031	0.037	0.044	○
7	92	×	73	×	0.16	×	61	39	×	0.013	0.024	0.039	0.084	0.110	0.114	×
8	91	×	64	×	0.31	×	442	191	×	0.003	0.010	0.022	0.027	0.033	0.037	○
9	95	○	85	○	0.04	○	47	248	○	0.002	0.008	0.014	0.021	0.027	0.034	○
10	92	×	71	×	0.29	×	547	201	×	0.015	0.023	0.031	0.034	0.035	0.039	○
11	95	○	85	○	0.09	○	38	50	○	0.002	0.010	0.014	0.019	0.025	0.029	○
12	97	○	89	○	0.04	○	26	22	×	0.003	0.010	0.015	0.022	0.029	0.036	○
13	98	○	87	○	0.04	○	34	9	×	0.006	0.010	0.019	0.025	0.031	0.040	○
14	99	○	89	○	0.03	○	24	15	×	0.008	0.014	0.022	0.027	0.034	0.040	○
15	102	○	91	○	0.04	○	38	439	○	0.038	0.044	0.048	0.050	0.052	0.055	○
16	96	○	85	○	0.10	×	38	39	○	0.004	0.010	0.017	0.024	0.045	0.078	○
17	93	×	83	×	0.11	×	93	73	×	0.004	0.007	0.009	0.011	0.015	0.022	○
18	94	×	79	×	0.17	×	149	51	×	0.007	0.015	0.038	0.088	0.189	0.348	×
19	93	×	82	×	0.12	×	73	73	×	0.003	0.006	0.008	0.011	0.015	0.024	○
20	97	○	88	○	0.02	○	138	260	○	0.002	0.010	0.016	0.023	0.029	0.038	○
21	90	×	64	×	0.44	×	459	115	×	0.002	0.054	0.173	0.320	0.330	0.357	×
22	97	○	91	○	0.03	○	16	22	○	0.007	0.012	0.020	0.025	0.031	0.035	○
23	95	○	84	×	0.10	×	42	26	×	0.005	0.012	0.020	0.033	0.049	0.122	×
24	98	○	89	○	0.03	○	24	12	×	0.009	0.016	0.022	0.029	0.034	0.043	○
25	98	○	92	○	0.03	○	27	79	○	0.005	0.009	0.009	0.009	0.013	0.021	○
26	97	○	91	○	0.02	○	24	55	○	0.011	0.015	0.016	0.018	0.020	0.021	○
27	97	○	91	○	0.02	○	19	48	○	0.007	0.009	0.012	0.014	0.016	0.019	○
28	97	○	92	○	0.02	○	21	23	○	0.003	0.007	0.009	0.010	0.011	0.013	○
29	95	○	82	×	0.11	×	61	40	×	0.003	0.009	0.022	0.037	0.067	0.192	×
30	98	○	91	○	0.04	○	19	49	○	0.004	0.005	0.009	0.018	0.025	0.041	○

TABLE 2 (Continued) – Relationships among three kinds of test results; JIS Chemical method, JIS Mortar-bar method and JIS Rapid method

Sample No.	JIS Rapid method						JIS Chemical method			JIS Mortar-bar method						
	Ultrasonic pulse velocity ratio (%) and judgment *		Relative dynamic modulus of elasticity (%) and judgment *		Length change (%) and judgment *		Sc (mmol/ℓ)	Rc (mmol/ℓ)	Judgment *	Expansion (%)						Judgment *
										2weeks	4weeks	8weeks	3months	4months	6months	
31	97	○	92	○	0.02	○	15	60	○	0.006	0.008	0.014	0.018	0.020	0.023	○
32	87	×	67	×	0.36	×	736	162	×	0.003	0.035	0.171	0.186	0.207	0.212	×
33	98	○	96	○	0.02	○	41	109	○	0.001	0.007	0.013	0.017	0.021	0.026	○
34	95	○	88	○	0.07	○	41	35	×	0.003	0.004	0.006	0.016	0.029	0.065	○
35	98	○	93	○	0.04	○	27	91	○	0.000	0.004	0.006	0.007	0.009	0.014	○
36	96	○	91	○	0.04	○	37	60	○	0.003	0.004	0.006	0.013	0.015	0.025	○
37	96	○	91	○	0.04	○	44	31	×	0.002	0.005	0.008	0.014	0.022	0.061	○
38	95	○	85	○	0.07	○	38	70	○	0.003	0.005	0.008	0.015	0.019	0.030	○
39	97	○	92	○	0.03	○	40	101	○	0.002	0.015	0.022	0.032	0.036	0.044	○
40	98	○	92	○	0.02	○	4	144	○	0.003	0.012	0.022	0.029	0.033	0.041	○
41	98	○	91	○	0.04	○	31	24	×	0.003	0.004	0.006	0.010	0.014	0.025	○
42	96	○	87	○	0.06	○	40	85	○	0.004	0.006	0.010	0.018	0.023	0.032	○
43	97	○	88	○	0.06	○	37	27	×	0.003	0.005	0.009	0.025	0.040	0.088	○
44	97	○	91	○	0.05	○	38	94	○	0.002	0.003	0.005	0.008	0.010	0.014	○
45	86	×	66	×	0.40	×	676	172	×	0.008	0.032	0.242	0.331	0.371	0.383	×
46	94	×	81	×	0.15	×	100	54	×	0.004	0.008	0.020	0.039	0.081	0.172	×
47	97	○	91	○	0.03	○	15	67	○	0.007	0.013	0.015	0.020	0.022	0.025	○
48	95	○	86	○	0.08	○	41	99	○	0.003	0.006	0.010	0.015	0.018	0.025	○
49	98	○	93	○	0.03	○	23	58	○	0.004	0.008	0.014	0.023	0.033	0.051	○
50	98	○	92	○	0.02	○	6	44	○	0.005	0.011	0.014	0.017	0.019	0.020	○
51	97	○	91	○	0.03	○	12	21	○	0.004	0.009	0.014	0.019	0.022	0.024	○
52	98	○	95	○	0.02	○	12	28	○	0.002	0.014	0.022	0.029	0.034	0.042	○
53	83	×	59	×	0.55	×	585	140	×	0.003	0.078	0.315	0.438	0.463	0.483	×
54	97	○	91	○	0.03	○	13	15	○	0.004	0.010	0.017	0.023	0.029	0.032	○
55	87	×	68	×	0.51	×	728	76	×	0.007	0.118	0.188	0.206	0.215	0.222	×
56	94	×	85	○	0.10	×	46	42	×	0.003	0.006	0.012	0.029	0.056	0.123	×
57	85	×	61	×	0.57	×	549	84	×	0.015	0.192	0.343	0.373	0.383	0.390	×
58	85	×	59	×	0.46	×	541	162	×	0.002	0.011	0.021	0.028	0.031	0.038	○
59	97	○	92	○	0.02	○	1	119	○	-0.001	0.003	0.004	0.007	0.007	0.007	○

Note) 1. Each of the measured values is the average of three measurements
2. *: ○ ··· Durable to AAR
× ··· Susceptible to AAR

Sc(mmol/l)	57	181	71	62	84	125	100	33	126	156	123	40	55	58	406	393	298	228	256
Rc(mmol/l)	74	77	124	129	67	75	74	44	130	118	115	174	110	154	74	79	52	72	111
Site	A1	A2	A3	B	C1	C2	C3	C4	D1	D2	D3	D4	D5	D6	E1	E2	E3	E4	E5

Expansion at six months (%): 0.5 / 0.1

(a) River sand

Sc(mmol/l)	35	103	52	49	33	32	41	22	58	75	68	—	31	—	222	189	108	36	48
Rc(mmol/l)	68	62	97	110	42	39	50	40	79	73	96	—	84	—	49	62	35	38	49
Site	A1	A2	A3	B	C1	C2	C3	C4	D1	D2	D3	D4	D5	D6	E1	E2	E3	E4	E5

Expansion at six months (%): 0.5 / 0.1

(b) River gravel

Note) Assessment by JIS Chemical method
: Innocuous
: Deleterious

Figure 1 Alkali-reactivity test results of river sand and gravel

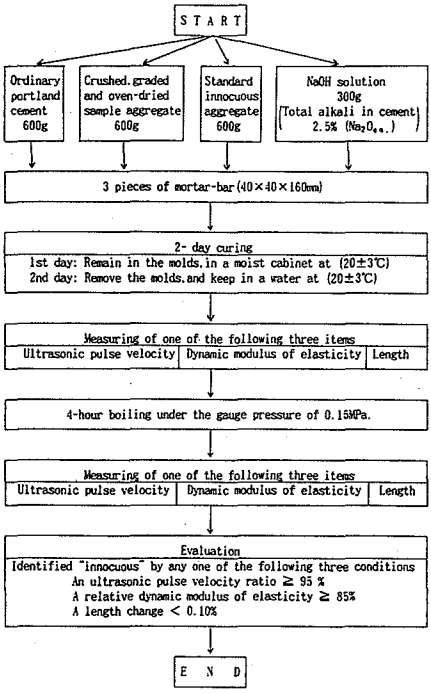


Figure 3 Flow of the Rapid test for aggregates (JIS A 1804)

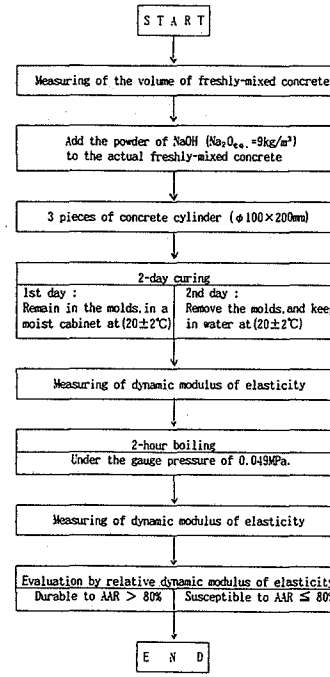


Figure 4 Flow of the Rapid test for concretes

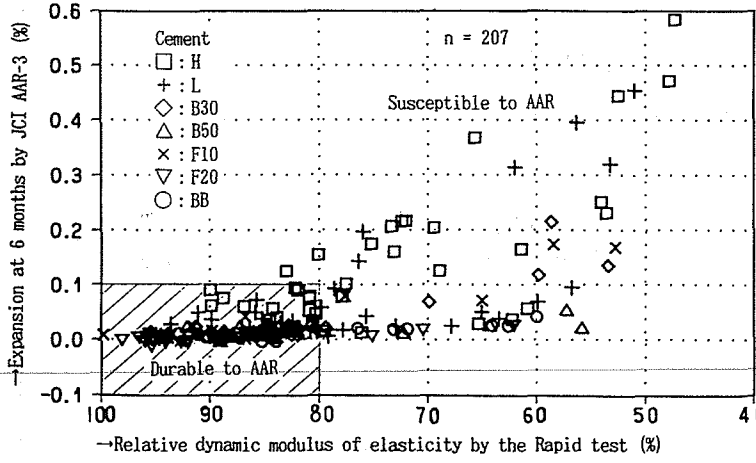
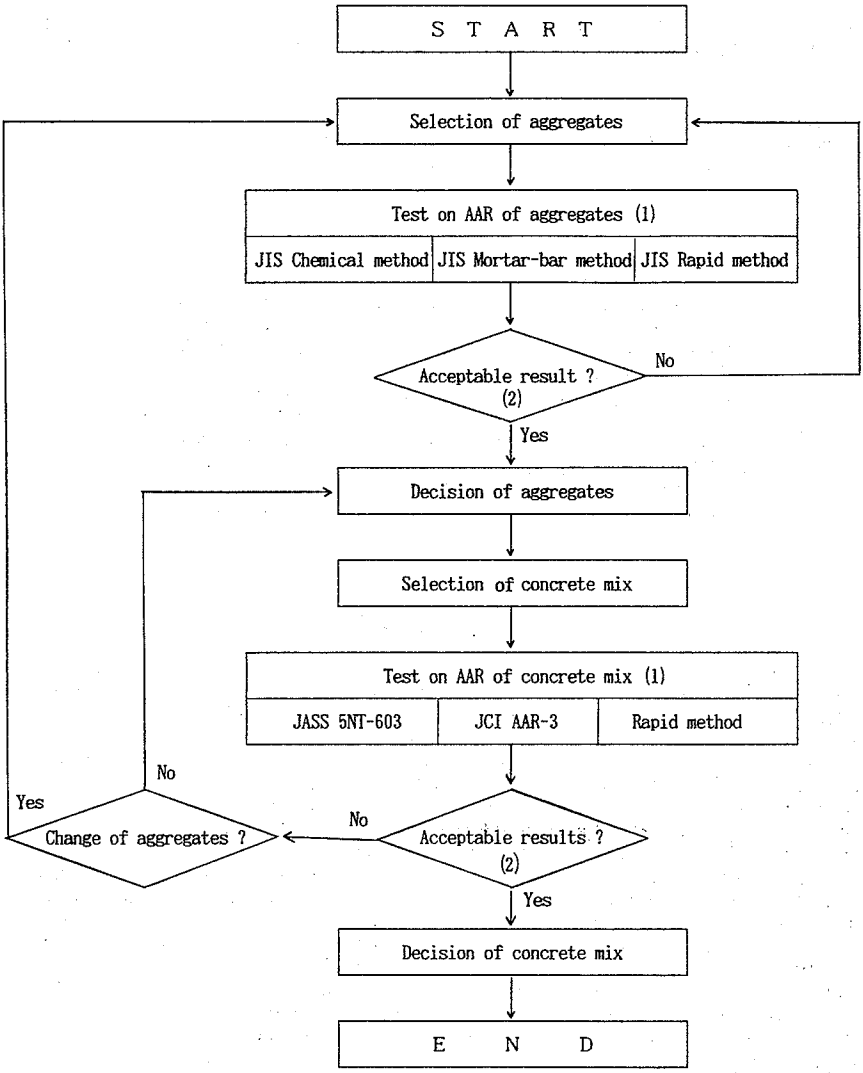


Figure 5 Relationships between rapid test results and expansion test results



Note) 1 : Rapid method and the others should be used for quality control and quality assurance, respectively.
2 : Judgement from an engineering point of view is essential.

Figure 6 Procedures for minimizing AAR in concrete