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A TEST METHOD ON RAPID IDENTIFICATION OF THE FUTURE SUSCEPTIBILITY OF ALKALI-AGGREGATE REACTION IN FRESH CONCRETE (FRESH-CON GBRC RAPID METHOD)

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1. INTRODUCTION

For the purpose of the rapid identification of the future susceptibility to alkali-aggregate reaction of an actual freshly mixed concrete, a new test method called Fresh-Con GBRC Rapid Method has been developed in General Building Research Corporation (GBRC) since 1986. This method is a modification of the GBRC Rapid Method which has been already developed for the rapid identification of the alkali reactivity of aggregates.

In order to minimize the risk of deterioration of concrete structures due to alkali-aggregate reaction, the following measures are effective.

(1) In the case of making concrete with innocuous aggregates, each aggregate should be checked by the GBRC Rapid Method.

(2) In the case of making concrete with any one of aggregates of unknown alkali reactivity, potentially deleterious aggregates and deleterious aggregates, the actual concrete should be checked by the Fresh-Con GBRC Rapid Method.

In this report, comparisons of the laboratory test results by the Fresh-Con GBRC Rapid Method with ones by a long-term expansion test, the outline of the Fresh-Con GBRC Rapid Method and field test results which were obtained by using actual ready-mixed concrete in cooperation with ready-mixed concrete plants.

2. LABORATORY TEST

2.1 Materials and Procedures

One hundred and twenty kinds of air-entraining concrete mixes were examined by both methods of the rapid test and a long-term expansion test. The long-term expansion test were carried out in accordance with the tentative JCI method in which additional alkali of 2.4kg/m³ (Na_2Oeq) were supplied by NaOH solution at mixing of each concrete. Materials used for the tests are listed in Table 1. Each concrete mix was designed so that unit weight of water and fine aggregate ratio should be 185kg/m³ and 45%, respectively.

Each concrete mix was designated as follows (ex. H-A-S-300) :

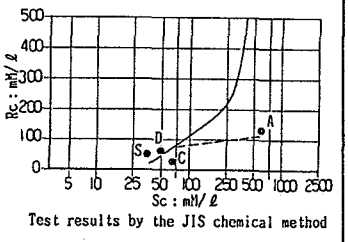
Cement - Coarse aggregate - Fine aggregate - Unit weight of cement

(H, L, BA, BB, FA, FB) (A, C, D, AD) (S, AS) (300, 350, 400, 450 : kg/m³)

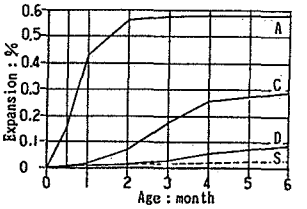
Total alkali content in each concrete mix is shown in Table 2.

Table 1 Materials

Materials	Desig.	Description
Cement	H	Ordinary Portland Cement (Na_2O_{eq}=0.97%)
	L	Ordinary Portland Cement (Na_2O_{eq}=0.58%)
	BA	Ordinary Portland Cement (Na_2O_{eq}=0.69%) + GGBS(30%) (Na_2O_{eq}=0.76%)
	BB	Ordinary Portland Cement (Na_2O_{eq}=0.69%) + GGBS(50%) (Na_2O_{eq}=0.80%)
	FA	Ordinary Portland Cement (Na_2O_{eq}=0.69%) + PFA(10%) (Na_2O_{eq}=0.83%)
	FB	Ordinary Portland Cement (Na_2O_{eq}=0.69%) + PFA(20%) (Na_2O_{eq}=0.97%)
Coarse aggregate	A	Crushed stone of andesite (Deleterious)
	C	Gravel of chert (Deleterious)
	D	Crushed stone of sand stone (Innocuous)
	AD	Agg.A (50%) + Agg.D (50%)
Fine aggregate	S	Sea sand (Innocuous)
	AS	Crushed sand made of Agg.A (50%) + Agg.S (50%)
Admixture	—	Air-entraining and water-reducing admixture



Test results by the JIS chemical method



Test results by the JIS mortar-bar method

2.2 Test Results and Discussion

Test results are shown in Fig.1 through 3. According to the test results, the following facts can be obtained.

Table 2 Alkali content in concrete (Na_2O_{eq} : kg/m³)

Cement used in concrete	Unit weight of cement			
	300kg/m³	350kg/m³	400kg/m³	450kg/m³
H	2.91	3.40	3.88	4.36
L	1.74	2.03	2.32	2.61
BA	2.28	2.66	3.04	3.42
BB	2.40	2.80	3.20	3.60
FA	2.49	2.90	3.32	3.74
FB	2.91	3.40	3.88	4.36

(1) An adequate correlation between the test results by the Fresh-Con GBRC Rapid Method and by the long-term expansion test are recognized.

(2) Concrete containing deleterious crushed sand has high susceptibility to alkali-aggregate reaction. This fact is identified not only by the long-term expansion test, but also by the Fresh-Con GBRC Rapid Method.

(3) Low-alkali cement, ground blast-furnace slag and flyash are effective for restraining of alkali-aggregate reaction in concrete. These effects can be identified by the Fresh-Con GBRC Rapid Method, as well as by the long-term expansion test.

The criterion for evaluation of the susceptibility to alkali-aggregate reaction of fresh concrete by the Fresh-Con GBRC Rapid Method was concluded by taking account of the criterion by the long-term expantion test, by which an expansion of more than 0.05% at the age of 3 months was consisidered "Deleterious".
The authors propose that an actual concrete should be evaluated as "Innocuous" by satisfying a relative dynamic modulus of elasticity of more than 80%.

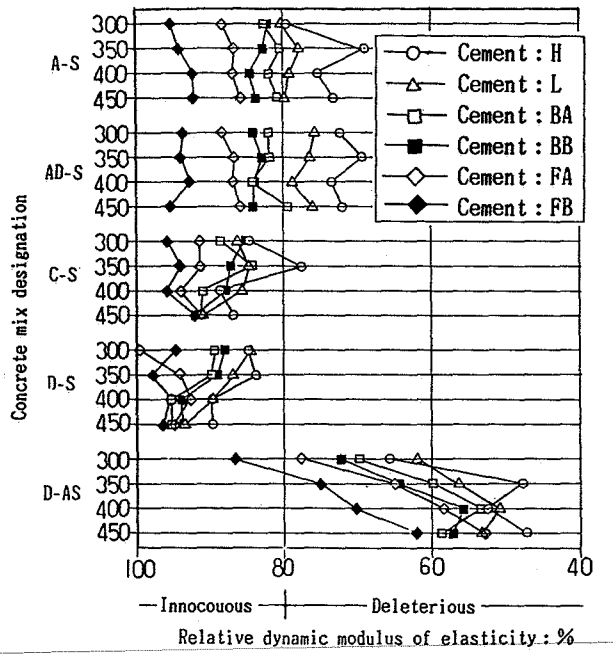


Fig.1 Test results by the Fresh-Con GBRC Rapid Method

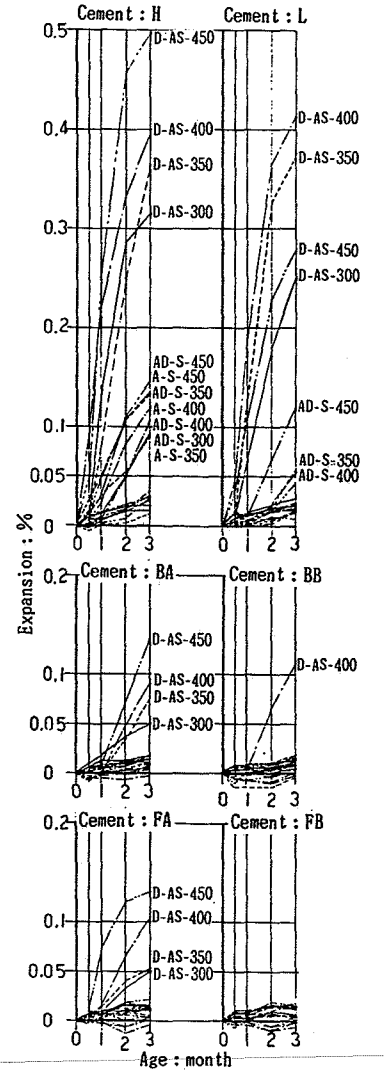


Fig.2 Test results by a long-term expansion test

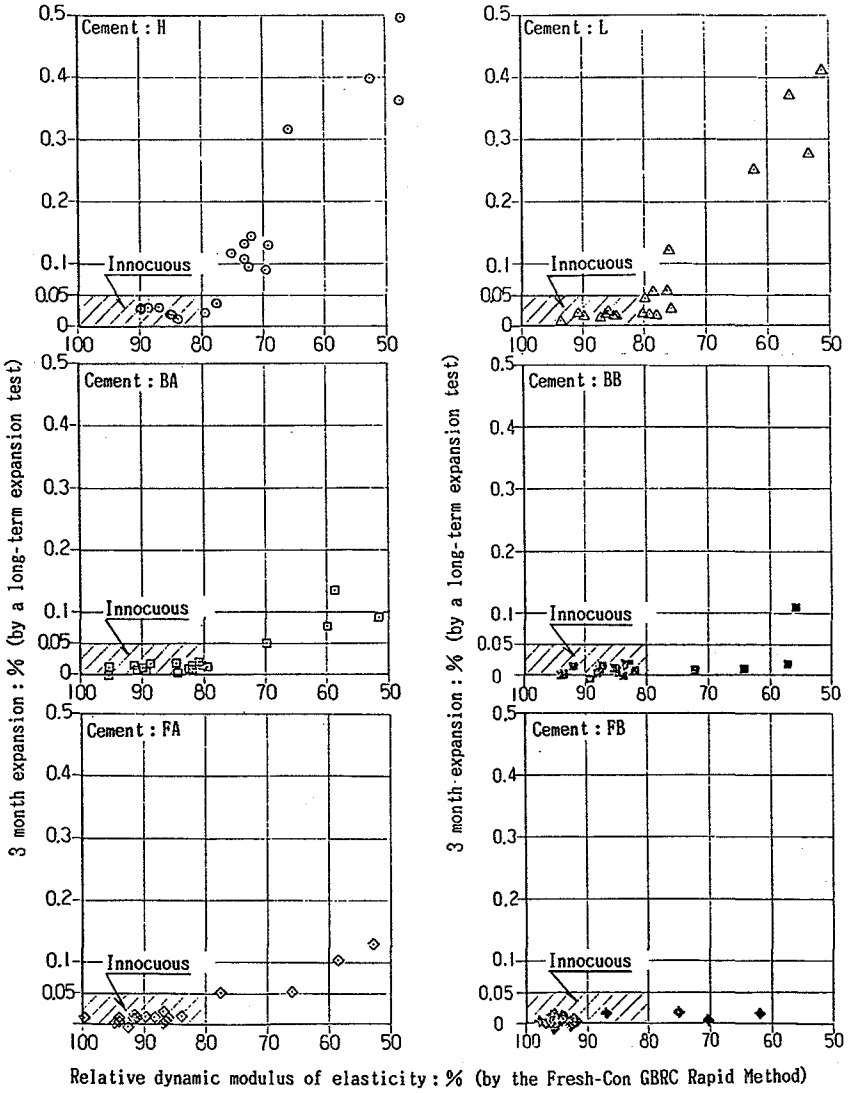


Fig.3 Relationship of the results between by the Fresh-Con GBRC Rapid Method and by a long-term expansion test.

3. FRESH-CON GBRC RAPID METHOD

In the rapid test, the future susceptibility to alkali-aggregate reaction of fresh concrete can be identified by relative dynamic modulus of elasticity after only two days. Fig.1 shows the flow of the Fresh-Con GBRC Rapid Method. Additional alkali of 9kg/m³ (Na_2Oeq) is applied to the actual freshly mixed concrete, by using the powder of NaOH. After casting three pieces of concrete cylinder, they are cured for two days ; for the first day in the molds in a moist cabinet at a temperature of (20±3)℃, for the second

day remove the molds and keep in weter at a temperature of (20±3)℃. They are then placed in boiling water in a pressure vessel (gauge-pressure : 0.5kgf/㎠, temperature : 111℃) for two hours. Deterioration of the concrete is checked just before and after boiling by dynamic modulus of elasticity of the cylinders.

An actual concrete should be evaluated as "Innocuous" by satisfying a relative dynamic modulus of elasticity of more than 80%.

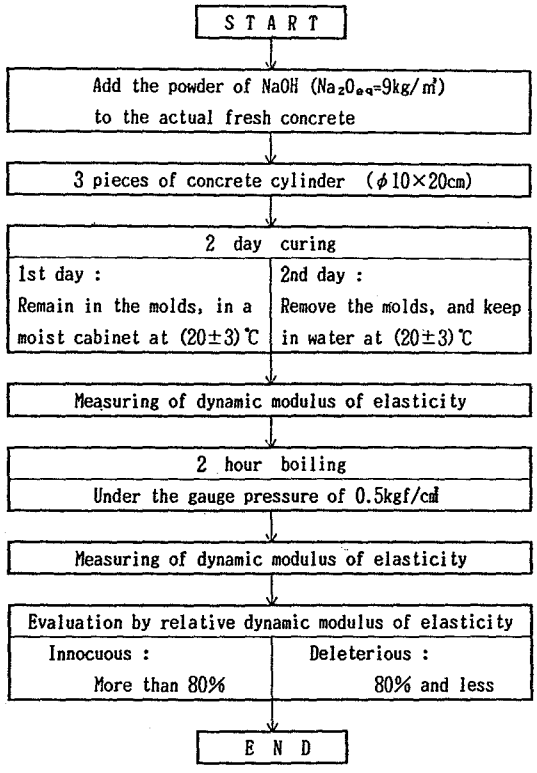


Fig.4 Flow of the Fresh-Con GBRC Rapid Method

4. FIELD TEST

The field test were carried out in cooperation with 26 ready-mixed concrete plants. In each ready-mixed concrete plant, specimens were cast and cured for the first day in accordance with the Fresh-Con GBRC Rapid Method. On the second day, specimens were carried to a laboratory of GBRC, and the following test procedures were carried out by GBRC.

Totally, fifty-five concrete mixes were examined by the rapid test. The test results are shown in Table 3. In the table, concrete mixes are designated as follows :

Ready-mixed concrete plant designation - Nominal strength (kgf/㎠) - Slump (cm) - Cement

- O : Ordinary Portland Cement
- H : High Early Strength Portland Cement
- BB : Blast-furnace Slag Cement (Class B)

Concrete mixes "D-255-12-O" and "D-285-15-BB" have deleterious crushed sand, and they are trial mixes. Other concrete mixes never have deleterious aggregate.

According to the test results, the following conclusions could be drawn.

(1) The susceptibility to alkali-aggregate reaction of each concrete mix could be reasonably evaluated.

(2) A concrete mix with deleterious aggregates and blast-furnace slag cement (D-285-15-BB) could be evaluated "Innoucuous".

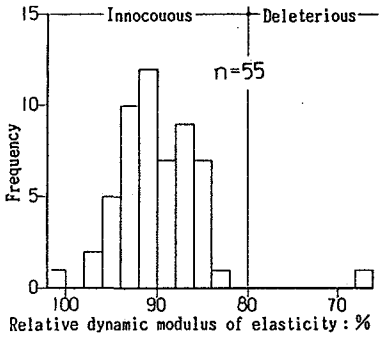


Fig.5 Test results by the Fresh-Con GBRC Rapid Method in cooperation with ready-mixed concrete plants

(3) All of concrete mixes with innocuous aggregates could be evaluated "Innocuous".

(4) The Fresh-Con GBRC Rapid Method is available for ready-mixed concrete plants in cooperation with a laboratory nearby.

5. CONCLUSION

Through the laboratory tests and the field tests, the availability of the Fresh-Con GBRC Rapid Method have been confirmed. This method is useful in order to not only prevent the deterioration of concrete structures due to alkali-aggregate reaction, but also reasonably utilize potentially deleterious aggregates and deleterious aggregates.

REFERENCES

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(2) Tamura H., Takahashi T. and Ohashi M., Summaries of Technical Papers of Annual Meeting Archtectural Institute of Japan, pp.457-460, 1988.

(3) Tamura H., Takahashi T. and Ohashi M., Cement & Concrete No.498, pp.13-20, 1988.

Table 3 Test results by the Fresh-Con GBRC Rapid Method in cooperation with ready-mixed concrete plants

Concrete mix designation	Alkali content : kg/m³	Relative dynamic modulus of elasticity : %				Evaluation
		No.1	No.2	No.3	Average	
A-210-15-0	1.85	90	91	90	90	
A-210-15-0	1.85	90	89	90	90	
A-270-12-0	1.71	89	89	90	89	
A-270-18-0	1.88	90	90	89	90	
B-180-18-0	2.05	91	91	91	91	Innocuous
B-255-18-0	2.53	92	92	92	92	
C-150-15-0	1.55	88	89	89	89	
C-255-18-0	2.15	87	88	88	88	
D-180-18-0	1.63	89	89	89	89	
D-255-12-0*	1.89	66	67	67	67	Deleterious
D-255-18-0	2.15	90	89	89	89	
D-285-15-BB*	1.76	88	88	90	89	
E-240-12-BB	1.72	94	94	94	94	
E-240-12-BB	1.72	95	94	94	94	
F-210-15-0	1.60	85	83	83	84	
F-300-12-BB	2.27	94	96	94	95	
G-240-12-BB	1.98	97	96	97	97	
G-240-12-BB	1.98	97	97	97	97	
H-240-12-BB	1.53	93	93	93	93	
H-300-12-BB	1.82	94	94	94	94	
I-210-12-BB	1.45	91	89	89	90	
I-240-8-H	1.67	85	86	85	85	
J-210-8-0	1.87	88	87	88	88	
J-210-15-0	2.03	88	87	86	87	
K-210-8-0	1.60	88	87	86	87	
K-210-18-0	1.83	82	85	85	84	
L-255-18-0	2.50	90	89	90	90	
L-285-18-0	2.75	90	90	90	90	
M-210-18-0	1.42	88	87	88	88	
M-300-18-0	1.86	91	91	91	91	
N-180-15-0	1.43	93	93	91	92	
N-210-15-BB	1.42	93	93	93	93	
O-225-18-0	2.03	87	90	89	89	Innocuous
O-255-18-0	2.24	86	86	88	87	
P-240-18-BB	1.20	101	100	101	101	
P-255-18-0	1.76	94	92	92	93	
Q-210-18-0	2.05	81	82	83	82	
Q-255-18-0	2.39	85	85	86	85	
R-240-12-0	1.69	86	85	87	86	
R-240-18-0	1.86	85	87	88	87	
S-210-8-BB	1.51	93	93	93	93	
S-225-18-0	2.06	85	84	84	84	
T-160-8-0	1.32	92	94	93	93	
T-180-8-0	1.37	89	89	88	89	
U-240-18-BB	1.90	91	89	89	90	
U-270-18-0	1.81	89	89	88	89	
V-255-18-0	2.46	87	87	85	86	
V-270-18-0	2.57	84	85	83	84	
W-210-18-0	1.98	87	87	87	87	
X-240-8-0	1.74	88	89	88	88	
X-240-18-0	2.00	89	90	89	89	
Y-240-8-0	1.77	85	85	84	85	
Y-255-18-0	2.17	85	84	86	85	
Z-180-8-0	1.35	87	87	87	87	
Z-350-15-0	2.41	92	92	93	92	

(Note) * : Deleterious crushed sand were used