STUDY ON A STANDARD RAPID TEST METHOD FOR IDENTIFICATION OF ASR SUSCEPTIBILITY OF CONCRETE

K.Kishitani, M.Kobayashi & H.Tamura
Committee of the Investigation and Studies on Standardization
of the Technique for Identification of ASR Susceptibility of Concrete
Tokyo, Japan

Abstract

In order to certify the durability to ASR in a given freshly mixed concrete, the final draft of a standard rapid test method for identification of susceptibility to ASR in concrete was developed and published. By the rapid test,the susceptibility can be identified two days after making specimens. For the acceleration of ASR in concrete, additional NaOH powder and a boiling procedure are applied,which is very similar to the rapid method for aggregates JIS A 1804 standardized in 1992.

This paper describes the outline of the rapid test procedures and main points of experimental results obtained during five years from 1989 through 1993 by the committee.

Keywords : *ASR,concrete,rapid test,standard test method*

Introduction

In Japan,in order to prevent premature deterioration of concrete structures due to ASR, several test methods have been standardized. These comprise two groupes:one is for the evaluation of alkali reactivity of aggregates,and the other for the future susceptibility to ASR of a given concrete mix. The former includes a chemical method (JIS A 5308 Appendix 7 which was developed by modifing the chemical method in ASTM C 289),a mortar bar method (JIS A 5308 Appendix 8 which was developed by modifing the mortar bar method in ASTM C 227) and recently a rapid method (JIS A 1804). The second group includes both long-term expansion test methods in JASS 5N T-603 and JCI AAR-3 standardized in 1991 for concrete structures in nuclear power stations by the Architectural Institute of Japan and for general concrete structures by the Japan Concrete Institute, respectively.

The rapid test method JIS A 1804 was published in 1992 as one of the standard test method series for production control of concrete designated as JIS A 1800s[1]. The rapid test method presented in this paper has been developed by modifing the rapid test method in JIS A 1804 and for the evaluation of the future susceptibility to ASR of a given concrete mix.

The final draft of a standard test method presented in this paper has been also prepared for one of JIS A 1800s. This draft was established based upon the comprehensive investigations conducted in the committee organized by the National Ready Mixed Concrete Industry Association under the guidance of Agency of Industrial Science and Technology in the Ministry of International Trade and Industry from fiscal 1989 to 1993 including laboratory test,field tests and a repeatability test [2]. This paper outlines the test procedures and main points of the experimental results.

Rapid test procedures

The flowchart of the rapid test is illustrated in Fig. 1. The outline of the rapid test method is described below.

Main apparatus used in the test are three molds for cylindrical specimens of Φ100 ×200 mm,a reaction accelerating apparatus capable of a gauge pressure of 0.049 MPa (temperature:111 ℃) and an apparatus for measuring dynamic modulus of elasticity.

Three cylindrical specimens of Φ100×200 mm are made of a given freshly mixed concrete. Prior to casting concrete in the mold,NaOH powder shall be added to the concrete. Amount of NaOH shall be adjusted so as to be 9 $kg/m^3(Na_2Oeq)$ of additional alkali in the mix.

In order to simply measure the concrete volume, a vessel of 7ℓ for air content measurement can be used. 81.3 g of NaOH powder should be added to 7ℓ of freshly mixed concrete. Small spherical powder of NaOH (0.7 mm in diameter,TOSO-PARL (Brand name)) is convenient for the test. Just after casting concrete,the surface of specimens shall be finished by a trowel.

Then the specimens shall be cured for two days:for the first day remained in the molds in a moist cabinet at (20±3) ℃,for the second day removed from the molds and kept in water at (20±3) ℃.

After the two-day curing,in order to accelerate chemical reaction,three specimens shall be boiled in water at a gauge pressure of 0.049 MPa for two hours. Specifically mentioned,the water temperature shall be adjusted to 40 ℃ at the beginning of boiling,raised up to 111 ℃ within 30±10 minutes,maintained 111 ℃ for two hours, and then lowered to 20～40 ℃ within 30±10 minutes. After these treatment, specimens shall be taken off the vessel and dipped into water at 20 ℃ for 20 minutes before the following measurement.

In order to evaluate the susceptibility to ASR, the first resonance frequency of the specimens shall be measured just before and after boiling. Relative dynamic modulus of elasticity shall be calculated using the following formula.

$$\text{Relative dynamic modulus of elasticity} = \frac{\begin{bmatrix}\text{First resonance frequency} \\ \text{after boiling}\end{bmatrix}^2}{\begin{bmatrix}\text{First resonance frequency} \\ \text{before boiling}\end{bmatrix}^2} \times 100 \ (\%)$$

Test results can be obtained as mean value of the three results calculated down to the first decimal place.

In case of the relative dynamic modulus of elasticity of 80% and more after the boiling to that before the boiling,the concrete is evaluated"Durable to ASR (Grade A)". In case of less than 80%, the second test using 6 kg/m^3 ($Na_2Oeq.$) instead of 9 kg/m^3 of additional alkali in the mix shall be conducted. In case of 70% and more at the second test,the concrete is assessed"Durable to ASR (Grade B)". In case of less than 70% at the second test,the concrete is identified"Susceptible to ASR".

"Durable to ASR (Grade A)"concrete can be used for highly durable concrete structures. "Durable to ASR (Grade B)"concrete can be generally used,however,can not be used for highly durable concrete structures. "Susceptible to ASR"concrete can not be used generally,however,it can be used under extremely dry condition.

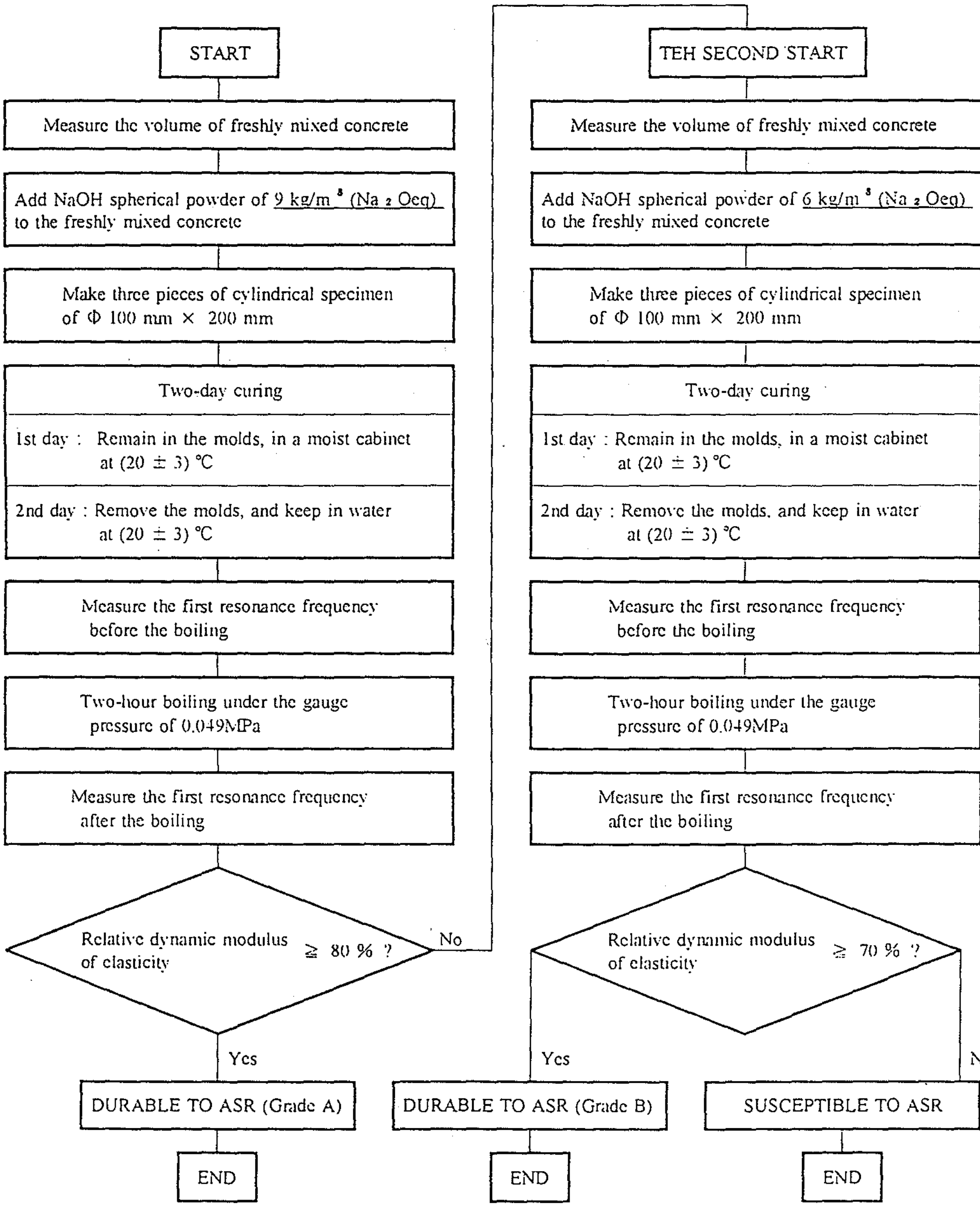


Fig.1 Flowchart of the rapid test for ASR in concrete

Experimental results

Laboratory test

Totally 206 concrete mixes have been examined in terms of the susceptibility to ASR using both some long-term expansion test in accordance with JCI AAR-3 and/or JASS 5N T-603 and the rapid test [2][3].

Expansion tests were carried out using concrete prism specimens of 75×75×400 mm. Specimens were stored in a moist condition of 40℃,100%RH,by being wrapped in wet paper and sealed in a plastic bag. In those expansion tests, additional alkali NaOH powder is also added to a given freshly mixed concrete. With regard to the additional alkali content,in JCI AAR-3,only one level of 2.4 kg/m^3 ($Na_2Oeq.$) is applied,however,in JASS 5N T-603,three levels of 1.2,1.8 and 2.4 kg/m^3 ($Na_2Oeq.$) are examined for obtaining the pessimum expansion between 0 to 3 kg/m^3 of additional alkali content by extrapolation. As for the threshold expansion for the evaluation is 0.10% at 6 month in the both expansion tests.

Many types of cement and aggregate,several kinds of aggregate combination,wide rage of unit weight of cement, consequently wide range of total alkali content in concrete were provided for the test. Fig.2 shows the relationships between the expansion test results and the rapid test ones. Based on the results,the threshold relative dynamic modulus of elasticity value of 80% was established.

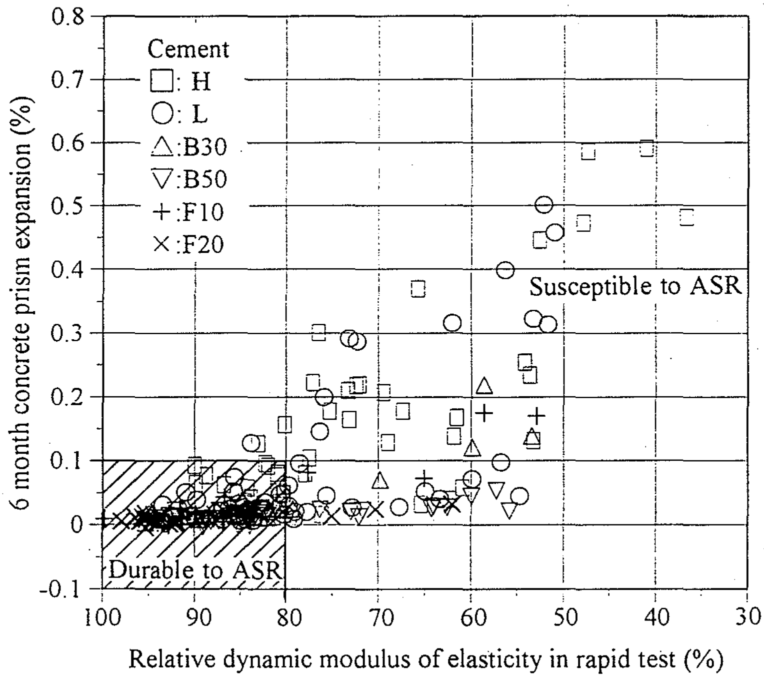


Fig. 2 Relationships between rapid test results and expansion test results

Field test

The rapid test using additional alkali of 9 kg/m^3 (Na_2Oeq.) was applied for eighteen kinds of ready mixed concrete mix actually produced in plants all over Japan. All the mixes use ordinary portland cement,and contain total alkali less than 3 kg/m^3. Long-term expansion test by JCI AAR-3 was also conducted using those mixes. According to the field tests,some concrete mixes showed extremely low values of relative dynamic modulus of elasticity by the rapid test,however,they did not show large expansion values.

Figs. 3 and 4 show the expansion test results and the relationships between additional alkali content and the rapid test results,respectively. Details of the concrete-making materials and concrete mix used in the expansion tests and the rapid tests are shown in Table 1 through 4. Fig. 3 includes the following three kinds of concrete mix. Mix No.1 using deleterious andesite gravel,which is discovered in the above mentioned field test,can be evaluated"Durable to ASR"based upon both the expansion test result and an observation field survey on existing concrete structures using the concrete mix,however showed extremely low value test results by the rapid test. Mix. No.2 can bealso evaluated"Durable to ASR"based upon the expansion test result, however showeda rapid test result very near the threshold value. Mix No.3 using crashed deleteriousandesite sand,which is considered the most susceptible to ASR in Japan,can beevaluated"Susceptible to ASR"based upon both the expansion test and the rapid test.

Judging from the results,the.second test using additional alkali of 6 kg/m^3 (Na_2O eq.) after the first test using additional alkali of 9 kg/m^3 and the threshold value 70% was established.

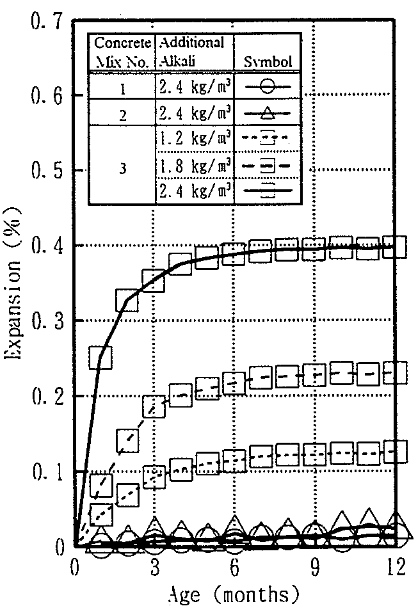


Fig. 3 Long-term expansion test results

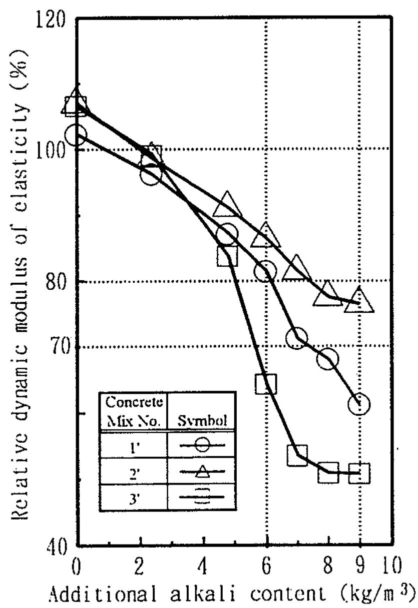
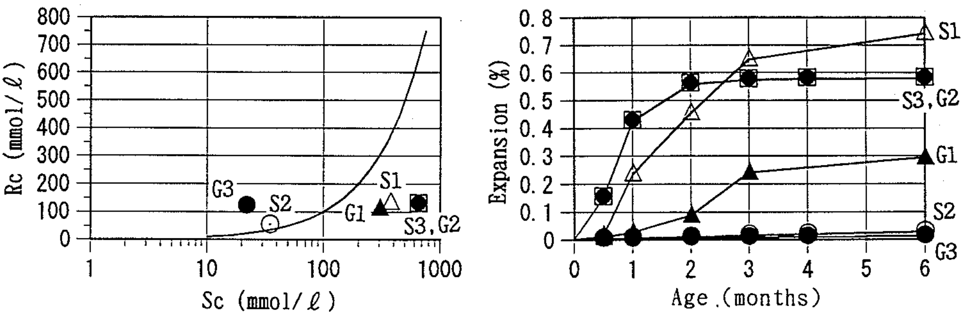


Fig. 4 Effect of additional alkali content on rapid test results

Table 1 Materials used for expansion tests

Ordinary portland cement	C_1	Total alkali(Na_2Oeq) : 0.68 %
	C_2	Total alkali(Na_2Oeq) : 0.58 %
	C_3	Total alkali(Na_2Oeq) : 0.65 %
Fine aggregate	S_1	River sand from SAI Alkali-silica reaction : Deleterious
	S_2	Marine sand from MUROKI Alkali-silica reaction : Innocuous
	S_3	Crushed sand from TESHIMA Alkali-silica reaction : Deleterious
Coarse aggregate	G_1	River gravel from SAI Alkali-silica reaction : Deleterious
	G_2	Crushed stone from TESHIMA Alkali-silica reaction : Deleterious
	G_3	Crushed sand from NAGAOYAMA Alkali-silica reaction : Innocuous
Chemical admixture	A	Air entraining water reducing agent



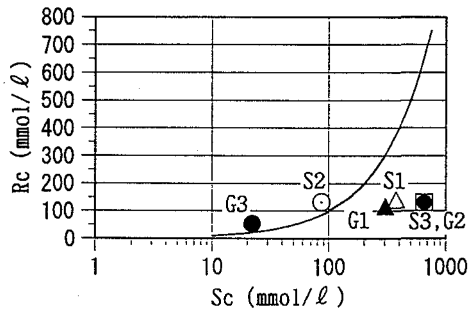
Test results by the JIS chemical method   Test results by the JIS mortar-bar method

Table 2 Concrete mixes for expansion tests

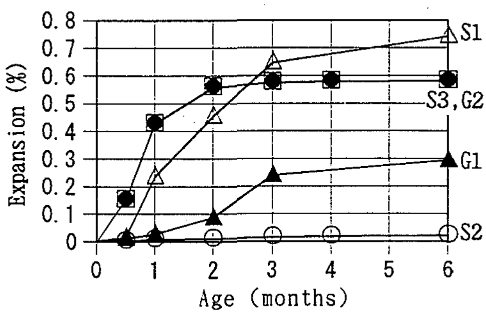
Concrete Mix No.	W/C	s/a	Unit weight (kg/m³)				Chemical admixture	Total alkali content
			Water	Cement	Aggregates			
					Fine	Coarse	A	(Na_2Oeq)
			W	C	S	G	(C×%)	(kg/m³)
1	58.0	47.1	172	C_1: 297	S_1: 851	G_1: 965	0.25	2.02
2	55.0	45.0	185	C_2: 350	S_2: 765	G_2: 910	0.25	2.03
3	52.0	45.3	191	C_2: 367	S_2: 529 S_3: 227	G_2: 981	0.25	2.39

Table 3 Materials used for rapid tests

Ordinary portland cement	C	Total alkali(Na_2Oeq) : 0.65 %
Fine aggregate	S_1	River sand from SAI Alkali-silica reaction : Deleterious
	S_2	River sand from IBE Alkali-silica reaction : Innocuous
	S_3	Crushed sand from TESHIMA Alkali-silica reaction : Deleterious
Coarse aggregate	G_1	River gravel from SAI Alkali-silica reaction : Deleterious
	G_2	Crushed stone from TESHIMA Alkali-silica reaction : Deleterious
	G_3	Crushed sand from MAKIOYAMA Alkali-silica reaction : Innocuous
Chemical admixture	A	Air entraining water reducing agent



Test results by the JIS chemical method



Test results by the JIS mortar-bar method

Table 4 Concrete mixes for rapid tests

Concrete Mix No.	W/C	s/a	Unit weight (kg/m^3)				Chemical admixture	Total alkali content
			Water	Cement	Aggregates			
					Fine	Coarse	A	(Na_2Oeq)
			W	C	S	G	(C×%)	(kg/m^3)
1'	55.0	46.0	175	C_1: 318	S_1: 812	G_1: 960	0.25	2.01
2'	55.0	46.0	189	C_2: 343	S_2: 783	G_2: 901	0.25	2.23
3'	55.0	46.0	189	C_2: 343	S_2: 548 S_3: 230	G_2: 933	0.25	2.23

After establishing the final draft of the rapid test,field tests using ready mixed concrete actually produced in plants all over Japan were carried out with cooperation of concrete testing laboratories under the National Ready Mixed Concrete Industry Association both in 1993 and 1994. Ready mixed concrete applied for the rapid tests have aggregate maximum size of 20 mm or 25 mm,slump of 80 mm through 180 mm and nominal compressive strength of 21 MPa,24 MPa or 27 MPa. All the concrete mixes contains total alkali less than 3 kg/m^3. Around 70% mixes out of 76 mixes were evaluated"Durable to ASR (Grade A)",and around 30% mixes were identified "Durable to ASR (Grade B)"in 1993. In 1994,around 65% mixes from 44 mixes were evaluated"Durable to ASR (Grade A)",and the lest"Durable to ASR (Grade B)".

Concluding remarks

In order to certify the durability to ASR in a given freshly mixed concrete,the rapid test method for identification of ASR susceptibility of concrete is a very effective measures. By the rapid test,the susceptibility can be identified two days after making specimens. In order to accelerate ASR in concrete,additional NaOH powder and a boiling procedure are applied,which is very similar to the rapid method for aggregates JIS A 1804 standardized in 1992. This final draft will be standardized as one of JIS A 1800s in the near future.

References

1. Kishitani,K.,Kobayashi,M. and Tamura,H. 1994,'The Rapid Test JIS A 1804', Cement & Concrete Composites,16,169-175.
2. Kishitani,K.,Kobayashi,M. and Tamura,H. 1992,'Development and Standardization of A Rapid Method for Identification of The Susceptibility to AAR in Concrete', Proc. of 9th Int. Conf. on AAR,535-542.
3. Tamura,H.,Takahashi,T. and Ohashi,M.1992,'Rapid Test for Identification of Susceptibility to Alkali-Silica Reaction in Concrete',CANMET/ACI Int. Workshop on Advances in Concrete Technology,Athens,Greece,11-13 May,133-152.