Test Method T363

Accelerated Mortar Bar Test for the Assessment of Alkali-Reactivity of Aggregate

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Revision Summary

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Ed 1/ Rev 0		Reformatted and Revision Summary Added	D Dash	May 1999
Ed 1/ Rev 1		2c Added (G Forster)	D Dash	February 2001
		Combine RTA T363 – 2001 with VICROADS RC376.03. Amend Table 2 (G Forster)	Draft	June 2008
Ed 2 / Rev 0		Updated, revised and reformatted June 2008 draft	G Forster	July 2011
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Note that Roads and Maritime Services is hereafter referred to as 'RMS'.

The most recent revision to Test Method T363 (other than minor editorial changes) is indicated by a vertical line in the margin as shown here.

Test Method T363

Accelerated Mortar Bar Test for the Assessment of Alkali-Reactivity of Aggregate

1. Scope

This Test Method sets out the procedure to determine the susceptibility of aggregates to alkali attack, leading to expansive reactions in concrete known as alkali aggregate reaction (AAR)*. The assessment is made by measuring the increase in length of representative mortar bars containing the aggregate concerned, during storage under prescribed test conditions.

** Note: The test method is suitable for assessment for Alkali Silica Reactivity and not for Alkali Carbonate Reactivity.*

2. References

The following documents are referred to in this Test Method:

(a) Australian Standards

AS 1141.3.1: Methods for sampling and testing aggregates - Sampling - Aggregates

AS 1141.3.2: Methods for sampling and testing aggregates - Rock spalls, boulders and drill cores

AS 1152: Specification for test sieves

AS 2349: Method of sampling portland and blended cements

AS 2701:2001: Methods of sampling and testing mortar for masonry constructions

AS 3972: Portland and blended cements

(b) American Society for Testing and Materials (ASTM)

ASTM C227-10: Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

ASTM C305-11: Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

ASTM C490/C490M-10: Standard Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar and Concrete

ASTM C511-09: Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

(c) RMS Test Methods

RMS T364: Concrete Prism Test for AAR Assessment

3. Apparatus

The following apparatus shall be used:

(a) *Balance* – of suitable capacity with a limit of performance not exceeding 0.5g.

(b) *Water Baths* – Two water baths are required. One water bath shall be capable of heating water and mortar bars from 23°C to 80°C over a three hour period. This may comprise a container of sufficient capacity, heated by a thermostatically controlled hot plate. The mortar bars shall not be in direct contact with the bottom of the container, but shall be separated from it by plastic stands or supports. The other water bath shall be thermostatically controlled to operate at 80±2°C. The volume of the baths shall be such that the ratio of the volume of solution to the volume of mortar bars placed in them is not less than 4. Alternatively, separate containers may be used inside an oven controlled to operate at 80±2°C.

(c) *Sodium hydroxide bath* – Sealable bath made of stainless steel or other suitable material to resist the action of sodium hydroxide, with a lid to prevent evaporation of solution and with racks to support mortar bars. This bath shall have temperature control as for the water bath of 80±2°C.

(d) *Length comparator and reference bar* – complying with requirements of ASTM C490/C490M. Alternatively, a suitable digital comparator with the same accuracy can be used.

(e) *Mixer, paddle and mixing bowl* – complying with ASTM C227.

(f) *Moulds* – 25 mm × 25 mm × 285 mm length with stainless steel studs, complying with ASTM C490/C490M. A gang of three mortar bar moulds is convenient for this purpose.

(g) *Oven* – thermostatically controlled to operate at a temperature within the range 105°C to 110°C.

(h) *Flow table, mould and calliper* – complying with the requirements of AS 2701, Section 5 and Appendices B and C.

(i) *Sieves* – 4.75, 2.36, 1.18 mm and 850, 600, 300 and 150 μm complying with AS 1152.

(j) *Tamper* – rubber compound or timber complying with AS 2701, Section 5.

(k) *Timer* – readable to one second.

(l) *Trowel* – having a steel blade 100-150 mm long with straight edges.

(m) *Mixing and curing room or cabinets* – laboratory and storage facility conditions as detailed in ASTM C511, protecting the specimens from dripping water.

(n) *Burette, pipette and beakers for titrations.*

4. Reagents

(a) *Sodium hydroxide solution* – 1M±0.05 NaOH solution.

(b) *Hydrochloric acid* – 1M HCl solution.

(c) *Phenolphthalein indicator.*

(d) *Water* – distilled or deionised to be used as mixing water.

5. Sampling and Preparation of Cement and Aggregate

5.1 Sampling

(a) Obtain a sample of General Purpose cement complying with the requirements of AS 3972 in accordance with AS 2349.

(b) Obtain a sample of the aggregate to be tested in accordance with AS 1141.3.1. Rock spalls, boulders or drill cores shall be sampled in accordance with AS 1141.3.2.

5.2 Preparation of Cement

The cement shall be sieved over the 850 μm sieve to remove lumps. Cement older than 6 months and that not maintained under sealed conditions shall not be used.

5.3 Preparation of aggregate

The aggregate to be tested shall comply with the grading given in Table T363.1.

Table T363.1
Aggregate Grading Requirements

Sieve sizes (square openings)		Percentage by mass
Passing	**Retained**	
4.75 mm	2.36 mm	10
2.36 mm	1.18 mm	25
1.18 mm	600 µm	25
600 µm	300 µm	25
300 µm	150 µm	15

(a) Naturally occurring fine aggregate (after processing)

Sieve the fine aggregate over the 4.75 mm sieve and discard any material retained on that sieve.

(b) Coarse aggregate and fine aggregate produced from crushing

(i) Crush the coarse aggregate sampled in 5.1(b) and sieve the material into the individual sizes as shown in Table T363.1.

(ii) Wash each size over the sieve on which it is retained to remove the fine dust and adhering particles.

(iii) Dry each size to constant mass in an oven operating at 105°C to 110°C.

(iv) Combine the individual sizes to provide a grading as shown in Table T363.1. Store the dried material in containers with tight fitting lids until used. Dried material may be kept in individual sizes in the separate containers, if required.

(c) Rock spalls, boulders or drill core

(i) Thoroughly wash the sample of rock spalls, boulders or drill core, as sampled in 5.1(b), using a stiff wire brush if necessary, to remove adhering clay or soft weathered stone.

(ii) Crush the sample to about 50 mm maximum aggregate size.

(iii) Sieve the crushed sample over a scalping screen and discard the material that passes the screen. If the material is not homogeneous, remove particles which vary from the bulk sample.

Note: The scalping procedure in this test method simulates the anticipated quarry practice, by removing from the test portion material which would not be representative of the quarried product. The size of the scalping screen should be selected on this basis.

(iv) Crush the material retained on the scalping screen so as to obtain sufficient particles of the sizes shown in Table T363.1.

(v) Proceed as detailed in Clause 5.3(b) (ii) to (iv).

6. Preparation of Mortar Bars

The mortar shall consist of:

1 part of cement by mass;

2.25 parts of aggregate prepared to the grading specified in Table T363.1, by mass.

Manufacture at least three mortar bars for each aggregate tested. The amount of materials needed for 3 mortar bars should be about 450 g cement and 1012 g of dry, graded aggregate.

Mix the mortar in accordance with ASTM C305, noting that the mixer with approximately 5 litre bowl and appropriate paddle shall be used for mixing the amount of materials needed for one set of 3 mortar bars. The sequence of addition of the mix ingredients is different in this method from that of AS 2701 Section 3, in which the dry materials are mixed first and water added subsequently.

Note: Mixing of the dry cement and other ingredients can cause a great deal of dust and for this reason the procedures of ASTM C305 and ASTM C227 are preferred.

The amount of distilled or deionised water for mixing the mortar shall be sufficient to produce adequate flow of the mortar of 5 to 20 mm (which is the same as 5 to 20% for a 100 mm mould).

Note: For most aggregates a water/cement ratio of 0.42 - 0.45 by mass should produce the desired flow. Adjustments to the amount of water may be needed for some aggregates with very low or very high water absorption.

Measure the flow in accordance with Clause 5.5 of AS 2701, except that the flow table shall be given 10 drops in 6 seconds from a height of 12 mm (rather than 25 drops in 15 seconds).

Note: As an example, if the internal diameter of the flow mould is 100 mm and the average diameter of the mortar mass after the flow test is 118 mm, then the % flow would be:

$$F = \frac{D_2 - D_1}{D_1} \times 100 = \frac{118 - 100}{100} \times 100 = 18\%$$

The reference to a flow of 110 ± 5 in Clause 5.4 of AS 2701 is incorrect.

A flow of 5-20% shall be achieved. If the flow is larger than this range, then discard the sample and prepare a new batch. If the flow is smaller, then return the sample to the mixer, add a few millilitres of water and remix for 30 seconds and retest for flow. If the flow is in the prescribed range, then return the sample to the mixer and remix for 30 seconds again.

After mixing is completed, record the flow and water/cement ratio of the mortar and prepare the mortar bars in accordance with ASTM C490/C490M. The gauge length of the mortar bars, so prepared, shall be 250 mm.

7. Procedure

Cure and measure the mortar bars as follows:

(a) Immediately after the specimen in the mould has been prepared, place the filled mould in a fog-room at 23±2°C, or a moist cabinet (relative humidity very close to 100% but not less than 98%) for 24±2 hours. It is good practice to place a strip of plastic on the top surface of the mould to protect the mortar from dripping water if a fog-room is used.

(b) Remove the moulds from the storage cabinet or room and demould the specimens ensuring that the bars are protected from loss of moisture and care is taken to ensure that the studs are not moved. Mark each mortar bar specimen with a unique identification. Mark with the letter (T) one end of the specimen which will always be at the top when placed in the comparator.

(c) Immediately place the mortar bar in the moist cabinet (relative humidity of very close to 100%, but not less than 98%) or fog-room at 23±2°C for 48±2 h, after which the measurement of length change shall be performed. The humidity of the moist cabinet shall be such that the surfaces of the specimens look moist during the curing period.

(d) If using a dial gauge, record the reading for the reference bar. If using a digital comparator, zero the unit when the reference bar is placed in the comparator in the correct position.

(e) Remove the mortar bars from the moist room and keep under a moist cloth. Take mortar bars one at a time and record the initial reading (L_1) of each mortar bar in the length comparator to the nearest 0.002 mm.

(f) Immediately place the mortar bar in a water bath (room temperature) and heat gradually at a rate of 18-20°C/hr to a temperature of 80±2°C in three hours and maintain the mortar bars at this temperature for 1 hour.

(g) Remove the mortar bars from the water bath, one at a time, wrap the bar in plastic and dry the end gauge studs on a towel. Using the comparator, record the length of the bar (L_2). Complete this process within 15±5 s of removing the specimen from the water.

Note 1: The reference bar should be read prior to measuring each set of specimens since the heat from the mortar bars may cause the length of the comparator to change.

Note 2: The thermal expansion of the mortar bar can be calculated based on the L_1 and L_2 measurements, if required.

(h) Immerse the mortar bar in the bath containing the 1M sodium hydroxide solution at 80±2°C. Ensure that the bars are immersed and supported in the bath so that the solution has access to the whole bar. The bars shall not touch the sides of the bath or each other and shall be immersed always whilst soaking. The bars, if stood upright, shall not be supported by the metal gauge stud.

(i) Make subsequent comparator readings of the specimens (L_n) as detailed in Step (g) 1, 3, 7, 10, 14, and 21 days after placing in the 1M NaOH solution at 80°C.

Note: It is good practice to continue the measurements at least until 28 days to note the behaviour of the mortar bars after the prescribed 21 days.

(j) Measure the concentration of the NaOH bath solution by titration with the hydrochloric acid solution and the phenolphthalein indicator and adjust the concentration, as necessary, to meet the requirements of 1M ±0.05M NaOH.

8. Calculations

Calculate the following:

(a) The expansion (E_n) of each mortar bar from the following equation:

$$E_n = \frac{L_n - L_2}{250} \times 100$$

(b) If required, the value of thermal expansion, *TE*:

$$TE = \frac{L_2 - L_1}{250} \times 100$$

where:

E_n = expansion at the time n days, after immersion in the 1M NaOH solution at 80°C, in percent

L_n = comparator reading at time n days after immersion of mortar bars in the 1M NaOH solution, in mm

L_1 = initial comparator reading, in mm

L_2 = comparator reading after heating to 80°C in the water bath, in mm

(c) The mean expansion of the three mortar bars for each batch.

9. Reference Testing

(a) A reference test shall be carried out to demonstrate that the testing laboratory, its equipment, procedures and staff are capable of testing any aggregate with a defined within-laboratory repeatability.

(b) For reference testing, the above procedures shall be carried out on a known non-reactive aggregate, previously established to give a 21-day expansion of no more than 0.03%. Other aggregates proven to be insensitive to alkalies could also be used.

(c) If the expansion measured from the reference test does not exceed 0.03% at 21 days, the in-house procedures and parameters shall be deemed satisfactory. These in-house procedures and parameters shall be documented and strictly followed in all further testing. No further reference tests are required unless any of the documented procedure or parameters are changed. New sources of cement shall be tested in combination with the reference non-reactive aggregate to ascertain their soundness for this purpose and to determine their possible contribution to the measured expansion of project aggregates, for example through MgO hydration.

(d) If the expansion measured from the reference test exceeds 0.03% at 21 days, the in-house testing procedure and parameters shall be examined and appropriately altered. Further reference tests shall be carried out until the measured expansion is less than 0.03%.

10. Test Report

Report the following:

(a) Type and source of aggregate, rock spalls, boulders or drill core.

(b) Type and source of cement.

(c) Flow and water/cement ratio of the mortar.

(d) For each required time, the expansion, in percent, to the nearest 0.001 and the number of days after placement in the 1M NaOH solution.

(e) Observations of cracks or other features revealed by examination of the specimens during and after the test.

(f) When required, a plot of the expansion versus time of soaking.

(g) The number of this test method, i.e. RMS T363.

Annexure T363/A - Aggregate Reactivity Classification

(Normative)

Aggregate shall be classified based on the 10 and 21 days expansion values in accordance with Table T363/A.

Table T363/A
Aggregate Reactivity Classification

Mortar Bar Expansion (%) in 1M NaOH (80°C)		Classification
10 days	21 days	
< 0.10*	< 0.10*	Non-reactive
< 0.10*	≥ 0.10*	Slowly reactive
≥ 0.10*	>> 0.10*	Reactive

* 0.15% for naturally occurring fine aggregates

Some glassy basalts may cause excessive mortar bar expansion, due to the production of fine glassy particles in the fine aggregate grading required for mortar bars. The reactivity of coarse aggregate of the same source needs to be verified, because the glassy phase within compact coarse basalt aggregates may not be accessible to alkali, and may not cause excessive concrete expansion. Concrete prism tests in accordance with RMS T364 or concrete block tests may be required for this purpose. Experience has shown that concrete prisms made with such basalts may or may not expand, which indicates that each aggregate needs to be judged individually.

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