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RILEM TC 106-AAR: ALKALI-AGGREGATE REACTION

Recommendations

A – TC 106-2 – Detection of potential alkali-reactivity of aggregates – The ultra-accelerated mortar-bar test
B – TC 106-3 – Detection of potential alkali-reactivity of aggregates – Method for aggregate combinations using concrete prisms

The texts presented hereafter are drafts for general consideration. Comments should be sent to the TC Chairman: Dr. Philip J. Nixon, Building Research Establishment, WD2 7JR Garston Watford, United Kingdom; e-mail: nixonP@bre.co.uk, by 31 December 2000.

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INTRODUCTION

The methods confirm and supersede drafts published in 1996. The progress of TC 106 has been reviewed by Nixon and Sims in 1996 [1] and again in a recent issue of *Materials and Structures* [2]. In their 1996 review, Nixon and Sims included two draft test methods: the ultra-accelerated mortar-bar test (TC 106-2) and the concrete prism test (TC 106-3). These tests have now been subjected to further development by TC 106, including some modifications recommended by the 'STAR' consortium following their trials for the European Commission [3], and final versions of the tests are provided in this paper.

Work is continuing on a petrographical examination procedure (TC 106-1) and this will be published separately in due course. TC 106 is also actively developing various other AAR test methods (see reference [2]), as well as overall guidance for their application and interpretation.

REFERENCES

[1] Nixon, P., Sims, I., 'Testing aggregates for alkali-reactivity, Report of RILEM TC 106', *Mater. Struct.* **29** (190) (1996) 323-324.
[2] RILEM Recommendation TC 106-AAR: International assessment of aggregates for alkali-aggregate reactivity, *Mater. Struct.* **33** (2000) 88-93.
[3] European Commission, 'Standard Tests for Alkali-reactive Rocks, Final report', DGXII contract no SMT4 - CT96 - 2128 STAR Project.

A – TC 106-2 – Detection of potential alkali-reactivity of aggregates – The ultra-accelerated mortar-bar test

1. FOREWORD

This draft method has been prepared by RILEM TC 106-AAR (Alkali-Aggregate Reaction) - Accelerated Tests. It is based on the South African NBRI (National Building Research Institute) accelerated test method.

2. SCOPE

This test method is intended to determine rapidly the potential alkali-reactivity of aggregates through the evaluation of the expansion of mortar-bars immersed in NaOH solution at elevated temperature, as specified in

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the method. The test may be also used in experiments to assess the pessimum behaviour of reactive aggregates (See Annex - A2). The test is not suited for the determination of the potential alkali-reactivity of aggregates containing more than 2% (by mass) of porous chert and flint (See Annex - A3).

3. SIGNIFICANCE AND USE

This test method provides a means of screening aggregates for their potential alkali-reactivity. It was developed as a quicker more reliable alternative to the ASTM C 227 mortar-bar test. It may be especially useful for aggregates that react slowly or produce expansion late in the reaction such as granite, rhyolite, andesite, volcanic tuff, gneiss, quartzite, hornfels, phyllite, sandstone, greywacke, shale, tillite, non-porous chert and flint, diatomite, quartz-bearing dolomitic limestones and quartz-bearing calcitic dolostones. It is recommended that a petrographic examination of the aggregates should accompany the accelerated test method (See Annex - A3).

4. PRINCIPLE

In this method prisms are moulded from mortar prepared with the aggregate to be tested. The prisms are demoulded after 24 ± 2 hours and their initial length measured. The specimens are then placed in water, transferred to an oven at 80°C ± 2°C for 24 hours, removed from the water and the length measured immediately before the temperature has dropped substantially (zero reading). The specimens are immediately placed in containers with a 1M NaOH solution already at 80°C ± 2°C, the containers sealed and placed in an oven at 80°C ± 2°C (subsequent 14 days). Length measurements are taken periodically.

5. APPARATUS

5.1 Sieves

A set of sieves conforming to series A of ISO 6274, having square apertures of 4 mm, 2 mm, 1 mm, 500 µm, 250 µm and 125 µm. Alternatively, the equivalent sieves of series B (4.75 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm and 150 µm) or C (5 mm, 2.5 mm, 1.25 mm, 630 µm, 315 µm and 160 µm) can be used.

5.2 Balance

A balance capable of weighing 1000 g with an accuracy of 1 g.

5.3 Measuring cylinders

Graduated in ml, with a capacity of 200 ml.

5.4 Mixer, paddle and mixing bowl

Mixer, paddle and mixing bowl, as used in the procedure for testing the strength of cement with plastic mortar.

5.5 Flow table

Flow table consisting essentially of a circular rigid table top, with a diameter of about 250 mm, that can be raised vertically by means of a cam, and dropped through a nominal height of 12.7 mm (*e.g.* conforming to ASTM C 230).

5.6 Mould for flow test

A frustum of a cone with height 50 mm, base diameter 100 mm and top diameter 70 mm (*e.g.* conforming to ASTM C 230).

5.7 Tamper

Tamper, made of non-absorbent, non-abrasive, non-brittle material and with a cross-section of 13 × 25 mm. A convenient length is 230 mm to 300 mm. The tamping face shall be flat and at right angles to the length of the tamper.

5.8 Prism moulds

Moulds, providing for prisms with a nominal length of 285 mm and a cross section of 25 mm × 25 mm (lengths in the range of 250 to 300 mm are also acceptable). The end plates of the moulds must have threaded holes in the centres to take stainless steel pins of 6 mm diameter and 20 mm length used for length measurements (see Note 1).

5.9 Length comparator

Consisting of:
- an apparatus to measure the length of the specimens conveniently and rapidly,
- a high-grade dial micrometer, or other measuring device, graduated to read in 2.5 µm units, accurate to within 2.5 µm in any 25 mm range, and within 5 µm in any 0.25 mm range. The measuring range shall allow for small variations (± 10 mm) from the nominal gauge length of the specimens,
- an Invar® reference bar (or similar) of the same nominal length as the specimens for checking the measuring device, before and after each set of readings.

5.10 Containers

Rigid containers for the test specimens made of plastic or other material resistant to corrosion by a solution of sodium hydroxide at a temperature of 80°C for a prolonged period of time. Each container must be of such dimension and shape to accommodate at least three specimens and must be provided with lids or other suitable means to prevent loss of moisture by leaking or evaporation. The prisms must be positioned and supported in such a way that the solution has access to the whole of the bar. It should further be ensured that the specimens do not touch each other or the sides of the container. The specimens, if stood upright in the solution, shall not be supported by the steel pins.

5.11 Storage

A cabinet or moist storage room maintained at a temperature of 20°C ± 1°C and a relative humidity more than 90% (*e.g.* conforming to EN 196-1).

5.12 Oven

An oven or room of suitable size to accommodate the required number of containers maintained at a temperature of 80°C ± 2°C.

5.13 Crusher

A laboratory-type crusher of suitable size and design capable of crushing aggregate to the prescribed size fractions.

NOTE 1: Moulds for prisms size 40 × 40 × 160 mm can also be considered.(See Annex - A5).

6. REAGENTS AND MATERIALS

6.1 Water

Distilled or deionised water.

6.2 Sodium hydroxide solution (NaOH)

Each litre of sodium hydroxide solution shall contain 40.0 g of NaOH dissolved in 900 ml of water and, after cooling to about 20°C, it shall be diluted with additional distilled or deionised water to obtain 1.0 litre of solution. The concentration of the solution shall lie between 0.99 and 1.01M. A new solution shall be prepared for each series of tests.

6.3 Cement

An ordinary Portland cement CEM I or ASTM type I with a minimum Na_2O equivalent (Na_2O + 0.658 K_2O) of 1.0%. The specific surface of the cement, when measured according to the air permeability method (*e.g.* EN 196-6), shall be greater than 450 m^2/kg. The autoclave expansion, determined according to ASTM test method C 151 shall be less than 0.20%. Alternatively the MgO soundness can be evaluated by Le Chatelier test (*e.g.* EN 196-3) and the increase in separation of indicators ends shall be 0 mm.

NOTE 2: Suitable reference cements are available from Norcem A.S, R&D Department, 3950 Brevik, Norway (contact Dr K. O. Kjellsen), or from National Council for Cement and Building Materials, Calibration Testing & Quality Control, 34 Km Stone, Delhi-Mathura Road (NH-2), Ballabgarh 121 004, Haryana State, India (contact Mr R. C. Wason).

7. PROCEDURE

7.1 Preparation of the aggregate sample

The quantity of sample delivered to the laboratory should be in accordance with the sampling procedures recommended in RILEM Recommendation TC 106-1 (Method for Petrographic Analysis of Alkali Reactive Concrete Aggregates) [1]. The material to be tested shall consist of particles ≤ 4 mm and ≥ 125 µm, graded according to 7.1.1, 7.1.2 and 7.1.3, washed and dried as indicated in 7.1.5.

7.1.1 Natural fine aggregate

The natural material proposed for use as fine aggregate in concrete shall be tested in the grading as submitted, except that particles retained on a 4 mm screen or equivalent shall be crushed and included.

NOTE 3: The particles retained on the 4 mm screen or equivalent shall be removed only if petrography has confirmed that they are no different from the particles passing through.

7.1.2 Crushed fine aggregate

The crushed material proposed for use as fine aggregate in concrete shall be tested in the grading prescribed in Table 1.

Table 1 – Grading requirements

Sieve Size		Mass, %
Passing	Retained	
4 mm	2 mm	10
2 mm	1 mm	25
1 mm	500 mm	25
500 µm	250 µm	25
250 µm	125 µm	15

(See Annex A7.1.2)

7.1.3 Coarse aggregate

The material proposed for use as coarse aggregate in concrete shall be processed by crushing and sieving to produce a graded sample in accordance with the requirements prescribed in Table 1. This sample shall be representative of the composition of the coarse aggregate as proposed for use.

NOTE 4: Coarse aggregate crushed to sand size may give increased expansion, owing to the increased surface exposed upon crushing. Therefore, if coarse aggregate tested by this method is found to be potentially reactive, tests should be performed on concrete specimens, according to RILEM Recommendation TC 106-3 (Method for Aggregate Combinations using Concrete Prisms)[2] to verify the results found with the mortar samples.

7.1.4 Fine and coarse aggregate

The material proposed for use as fine and coarse aggregate in concrete shall be separated by sieving on a 4 mm sieve or equivalent. Fine and coarse aggregate shall be tested separately as indicated in clauses 7.1.1, 7.1.2 and 7.1.3.

7.1.5 Final aggregate preparation

After the fine or coarse aggregate has been processed and washed to remove adhering dust or fine particles (< 125 µm) from the aggregate, dry the fractions at 100°C to 110°C for 16 hours and cool. Unless used immediately, store each fraction individually in a clean container provided with a tight-fitting cover.

7.1.6 Combining the aggregates

If the test method is to be used in an experimental programme to assess the pessimum behaviour of a reactive aggregate, undertake a petrographic examination of the test sample according to RILEM Recommendation TC 106-1 (Method for Petrographic Analysis of Alkali Reactive Concrete Aggregates) [1]. This examination should be sufficiently detailed to identify all the rock types or mineral constituents that compose the test sample. The results from the petrographic examination could then be used to establish a suitable test protocol (See Annex A7.1.6) such that any potentially damaging pessimum behaviour is identified.

7.2 Conditioning

The temperature of the moulding room, apparatus, dry materials, mixing water and of the cabinet or moist storage room shall be maintained at 20°C ± 2°C. The relative humidity of the moulding room and of the cabinet or moist storage room shall not be less than 65 ± 5% and 90 ± 5% respectively.

7.3 Proportioning of mortar

Proportion the dry materials for the test mortar using 1 part of cement to 2.25 parts of aggregate by mass. The minimum quantity of dry materials to be mixed at one time for making three 25 mm × 25 mm × 285 mm specimens shall be 400 g of cement and 900 g of aggregate.

Use a free water/cement ratio of 0.47 by mass, where the free water is the water available for hydration of cement and for the workability of the fresh mortar. The total water added to the mix is the free water plus the water absorbed by the aggregate to bring it to a saturated surface dry condition. Measure the workability of the mortar on a flow table (*e.g.* EN 1015-3). The flow value (mean diameter of the mortar) shall be in the range of 205 to 220 mm and, in the cases of mixes with a flow initially less than 205 mm, use a superplasticizer (not one combined with an air entraining agent) in order to achieve the required flow.

7.4 Moulding test specimens

Make at least three 25 mm × 25 mm × 285 mm specimens out of each one of two batches of mortar for every aggregate to be tested (see Annex A5).

Prepare the specimen mould with a suitable releasing agent that will not affect the setting of the cement or leave any residue that will inhibit the penetration of water into the specimen. Mix the mortar in accordance with the procedure for testing the strength of cement with plastic mortar (*e.g.* EN 196-1). Start moulding the specimens not more than 3 minutes after completion of the mixing of the mortar batch. Fill the moulds with two approximately equal layers, each layer being compacted with the tamper. Work the mortar along the surface of the mould with the tamper until a homogeneous specimen is obtained, making sure that the mortar is fully pushed under the reference inserts before a second layer is placed into mould. After the top layer has been compacted, cut off the mortar flush with the top of the mould and smooth the surface with a few strokes of the trowel.

NOTE 5: Particular care should be taken to attain a consistent compaction of the mortar, as the degree of compaction greatly influences the degree of expansion, the better the compaction the lower the expansion.

7.5 Initial curing and measurement

Place the moulds in the moist cabinet or in the moist storage room for a period of 24 ± 2 hours. Remove the specimens from the mould and, while they are being protected from loss of moisture, properly identify each specimen in such a way that they, when subsequently measured, are placed in the measuring equipment in the same manner. Make and record the length (Li) and all subsequent measurements to the nearest 0.002 mm.

Place the specimens made with each aggregate sample in a storage container with sufficient distilled or deionized water, at room temperature, to immerse them totally. Seal and place the containers in an oven at 80°C ± 2°C for a period of 24 hours.

Remove the containers from the oven one at a time.

Remove other containers only after the bars in the first container have been measured and returned to the oven. Remove the bars one at a time from the water and dry their surfaces with a towel or cloth paying particular attention to the two metal pins. Take the zero measurement of each bar (Lo) immediately after drying and read as soon as possible after the bar is in position. Complete the process of drying and measuring within 15 s of removing the specimens from the water.

The measuring device should be checked with the reference bar prior to and after measurement of each set of specimens .

7.6 Final storage and measurement

Place the specimens made with each aggregate sample in a container with sufficient 1M NaOH, preheated at 80°C ± 2°C, totally to immerse the specimens. The recommended volume proportion of sodium hydroxide solution to mortar-bars in a storage container shall be 4 ± 0.5 times the volume of the mortar-bars. Seal the container and return it to the oven.

Take subsequent measurements (Ln) of the specimens periodically, with a reading after 24 hours of immersion in the NaOH solution and at least three intermediate readings before the final reading at 14 days. If so desired, measurements may be taken at 24-hour intervals and may be continued beyond 14 days. All measurements should be taken at approximately the same time each day. The measuring procedure is identical to that described in clause 7.5 and the specimens are returned to their container after each measurement.

In some cases, the solution may become cloudy due to the presence of alkali-silica gels.

7.7 Safety measures

Reliable safety precautions should be taken and suitable personal protective equipment should always be used to avoid the hazards of the hot alkaline solution such as severe burns and injury to unprotected skin and eyes.

8. CALCULATION AND REPORTING OF RESULTS

8.1 Expansion

The linear expansion of each specimen is obtained by calculating the difference between the length of the specimen at each period of measurement (Ln) and the zero measurement (Lo), to the nearest 0.001% of the effective length, as follows:

$$\text{Expansion, \%} = 100 \times (Ln - Lo)/\text{Gauge length}$$

where:

Ln = reading taken at each period of storage in sodium hydroxide solution,

Lo = measurement of specimen before subjection to sodium hydroxide solution,

Gauge length = distance between inner ends of the metal pins, measured to the nearest 1 mm.

8.2 Expansion recording and further examination

Record and report to the nearest 0.01% the average expansion of the specimens for a given period (see Annex A5). In the case of breakage of specimens during tests, the test will be considered valid provided the average is based on at least four specimens (at least two from each of the two batches). For average values of expansion greater than 0.10%, the repeatability is considered satisfactory if the expansion of each specimen is within 10% of the average value. For average values of expansion less than 0.10%, the repeatability is considered satisfactory if, for each specimen, the deviation from the average value is within 0.01%. If these values are exceeded, deem the test invalid and repeat the test.

After the final measurement, the specimens shall be examined and any relevant features recorded. Warping, if observed, shall be measured on 3 moulded surfaces by placing the specimens on a plane surface, with curved ends facing downwards, and measuring the maximum separation between the specimen and the surface to the nearest 0.2 mm. Location, type and pattern of any cracking should also be recorded.

> *NOTE 6: If the mortar-bars exhibit an expansion that is judged to be deleterious, a petrographic examination of the interior of the bars that have expanded most should be carried out together with an examination of the internal crack pattern to confirm that the cause of expansion is likely to be an alkali-silica reaction [3]. If it has been concluded from the expansion results and supplementary examination of the prisms that a given aggregate should be considered potentially alkali-reactive, additional studies using the RILEM Recommendation TC 106-3 (Method for Aggregate Combinations using Concrete Prism) [2], may be appropriate to develop further information on its potential alkali-reactivity and to evaluate the effect of coarse aggregate, different aggregate gradings and different alkali contents of the concrete.*

9. TEST REPORT

The following information shall be given in the report:

- identification and source of the aggregate sample and reference to petrographic analysis, if available;
- type and maximum size of the aggregate;
- type of processing undertaken on the aggregate sample in the laboratory (washing, drying, crushing, sieving etc.);
- grading of the aggregate as used in the test;
- identification and source of the Portland cement;
- alkali content of the cement expressed as equivalent

sodium oxide (% Na_2O + 0.658 % K_2O);

- autoclave expansion or Le Chatelier value of the cement;
- Blaine fineness of the cement;
- workability of mortar (flow);
- type and content of superplasticizer (if used to achieve the mortar workability in the range of 105 to 120%), and its contribution to the alkali content of the mortar mix;
- size of the mortar-bars;
- tested combinations of the aggregate with a reference non-reactive fine material (if the pessimum behaviour has been investigated);
- initial expansion of the bars after 24 h of storage in water at 80°C;
- average percentage length change after each measurement of the specimens;
- a graph of the percentage length change vs time from the zero reading to the end of the 14-day period of immersion in NaOH solution;
- results of any warping measurements of the specimens;
- any significant features revealed by examination of the specimens and the sodium hydroxide solution during and after the test.

ANNEX

(comments relate to clauses as numbered in the method)

A2. SCOPE

With some reactive aggregates it has been found that there is a proportion of reactive constituents in the aggregate that leads to a maximum expansion. This proportion is called the "pessimum" content and the relationship between expansion and reactive constituents content is called the "pessimum behaviour" of the reactive aggregate.

A3. SIGNIFICANCE AND USE

It is recommended to start all screening of aggregates for their potential alkali-reactivity with a petrographic examination of the aggregate. On the basis of the results of the petrographic examination, a decision can be made with respect to further testing. If aggregates contain more than 2% (by mass) of porous chert and flint, further testing by means of the accelerated mortar-bar test is not recommended. It is reported (see Note A7) that application of the accelerated mortar-bar test to reactive aggregates containing porous chert and flint sometimes gives rise to misleading results and inappropriate approval of such aggregates.

NOTE A7:

[A1] E. Soers 'The Alkali-Aggregate Reaction in Belgium', Proceedings of the Advanced Seminar on Alkali-Aggregate Reaction – the European Dimension –, Queen Mary and Westfield College, University of London, London, 1990, 147-160.

[A2] STAR Project, 'Standard Tests for Alkali-reactive Rocks', Final Report, European Commission, DG XII, contract n° SMT4-CT96-2128, 1998, 148 pp.

A5. APPARATUS

The use of other mould sizes (*e.g.* 40 × 40 × 160 mm) can be used as an alternative option. In this case a minimum volume of 1.0 litre should be prepared for a single batch, according to clause 7 of the test method.

A relationship between the expansion of long thin (25 × 25 × 250 - 300 mm) prisms and short fat (40 × 40 × 160 mm) prisms, based on statistical data, is not available yet. A comparative programme has suggested a factor of 0.54 (Reference A2 of Note A7):

*Expansion % (40 × 40 × 160 mm) = 0.54 * Expansion% (25 × 25 × 250 - 300 mm)*

However it is not known whether this relationship would apply similarly to all aggregate combinations.

Different limits for the mortar-bar expansions must be considered for alternative specimen sizes.

A7.1.2 Crushed fine aggregate

Alternatively the equivalent sieves of series B and C of ISO 6274 could be used

A7.1.6 Combining the aggregates

If the aggregate sample is composed of,

a) particles of a single rock, sand, gravel or mineral type that has previously been shown not to have an associated pessimum behaviour and it is intended to use this aggregate unblended,

or,

b) the reactive constituent in a single rock, sand, gravel or mineral type is found at concentrations outside the pessimum limits previously established for the reactive constituent type and it is intended to use this aggregate unblended,

then only a mortar with an aggregate component composed wholly of the test aggregate needs to be tested.

Alternatively, if an aggregate sample is,

a) composed wholly or in part of a rock, sand, gravel or mineral type which has particles or mineral constituents that have an associated pessimum proportion and the reactive constituents are found in concentrations that are deemed to be potentially reactive, or it is either unknown or not prescribed where the "safe" limits lie,

or,

b) if it has not been established whether the rock or mineral constituent type has or does not have an associated pessimum proportion,

or,

c) if the sample is a blend of aggregate types where the behaviour of the aggregates when combined is unknown,

or,

d) if a petrographic analysis is not available,

then several combinations of test aggregate and non-reactive fine material will need to be tested, as indicated

Table A2 – Suggested Aggregate Proportions

Combination	Aggregate to be tested (%)	Reference non-reactive fine material (%)
I	100	0
II	50	50
III	25	75
IV	15	85
V	5	95
VI	0	100

in the following paragraph, in order to identify any pessimum behaviour.

The aggregate to be tested shall be mixed with a reference non-reactive fine material (natural sand or crushed rock) with the same grading as the sample under test. The material used for this purpose shall give an expansion of less than 0.05% by this test method (See Note A8) and shall not exhibit a pessimum behaviour. It should be preferably a non-siliceous material and previously evaluated. Some suggested proportions of test aggregate and reference non-reactive fine material are shown in Table A2. As preliminary tests, only three combinations should be used (*e.g.* I, II and IV). Special aggregates may require some other levels to make sure that any possible pessimum behaviour is identified.

> *NOTE A8: This expansion limit is deliberately more restrictive than is generally applied to identify non-reactive aggregates to ensure that the non-reactive reference aggregate has minimal effect on the results of this test.*

TC 106-2 REFERENCES

[1] RILEM Recommendation TC 106-1, ‘Petrographic analysis of alkali-reactive concrete aggregates’, (in preparation).

[2] RILEM Recommendation TC 106-3, ‘Detection of potential alkali-reactivity of aggregates - Method for aggregate combinations using concrete prisms’ (in this paper).

[3] Report of a Working Party, ‘The Diagnosis of Alkali Silica Reaction’ (British Cement Association, 2nd Edition, 1992), BCA, Slough (now Crowthorne), UK.

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B – TC 106-3 – Detection of potential alkali-reactivity of aggregates – Method for aggregate combinations using concrete prisms

1. FOREWORD

This method has been prepared by RILEM TC 106-AAR (Alkali-Aggregate Reaction) - Accelerated Tests.

2. SCOPE

The method covers the measurement of expansion of concrete produced by alkali-silica reaction. It enables the effect of specific combinations of aggregates to be investigated.

3. PRINCIPLE

Concrete test prisms are prepared from the aggregate combination under test and are stored in warm, humid conditions for 12 months to promote any alkali-silica reaction. Measurements are made at periodic intervals to determine whether any expansion has occurred. To promote further any potential for reaction, the prisms are made with a relatively high cement content and a high alkali cement such that the alkali level in the concrete is 5.5 kg sodium oxide equivalent per cubic metre of concrete. Sodium hydroxide is added to the mix when necessary to enhance the alkali level.

In order to identify the effect of specific aggregate combinations and any pessimum effects, there are options to test the coarse and fine test aggregates together or either in combination with a non-reactive material.

4. APPARATUS

4.1 Moulds

Three steel moulds suitable for casting concrete prisms of lengths 250 ± 50 mm and cross-section 75 ± 5 mm. The moulds shall have the facility for casting stainless steel reference studs into the mid-points of the end faces of the prisms (also see A4.1).

4.2 Length comparator

The length comparator should be such as to accommodate the shape of the reference studs in the prism and shall incorporate a gauge mounted rigidly in a vertical orientation. The graduation of the gauge shall not be greater than 0.002 mm and the error throughout the range of traverse shall be no more than 0.005 mm. Horizontally mounted comparators are not suitable for measuring wrapped prisms with non-planar surfaces.

4.3 Standard length gauge

This shall consist of an Invar® rod with ends machined to accommodate the reference studs.

4.4 Concrete mixing and casting equipment

This shall be suitable for mixing batches and vibrating into the moulds.

4.5 Specimen storage

Specimens shall be wrapped in twill weave cotton cloth (240 g/m^2 ± 30 g/m^2) of a width at least 10 mm greater than the length of the prism. They are then sealed inside polythene lay-flat tubing, 500 gauge, 180 mm wide, and secondly inside polythene bags, 500 gauge, approximately 500 × 250 mm.

The wrapped specimens are stored inside containers for maintaining a high relative humidity around the wrapped prisms during storage. A suitable design of container is shown in Fig. 1 (see also A4.5).

The containers are stored in a room or cabinet capable of being maintained at a temperature of 38 ± 2°C throughout its storage space.

4.6 Casting and measurement environment

A room maintained at 20 ± 2°C and relative humidity not less than 65 ± 5% is needed (see also A4.6).

5. MATERIALS

5.1 Sodium hydroxide

Sodium hydroxide of at least technical grade.

> *NOTE 1: CAUTION - care should be taken when handling this chemical (and concrete containing it) and suitable protective clothing should be worn.*

5.2 Portland cement

An ordinary Portland cement (EN(V)-1 CEMi 42.5 or ASTM Type I) with total alkali content of 0.9-1.2%

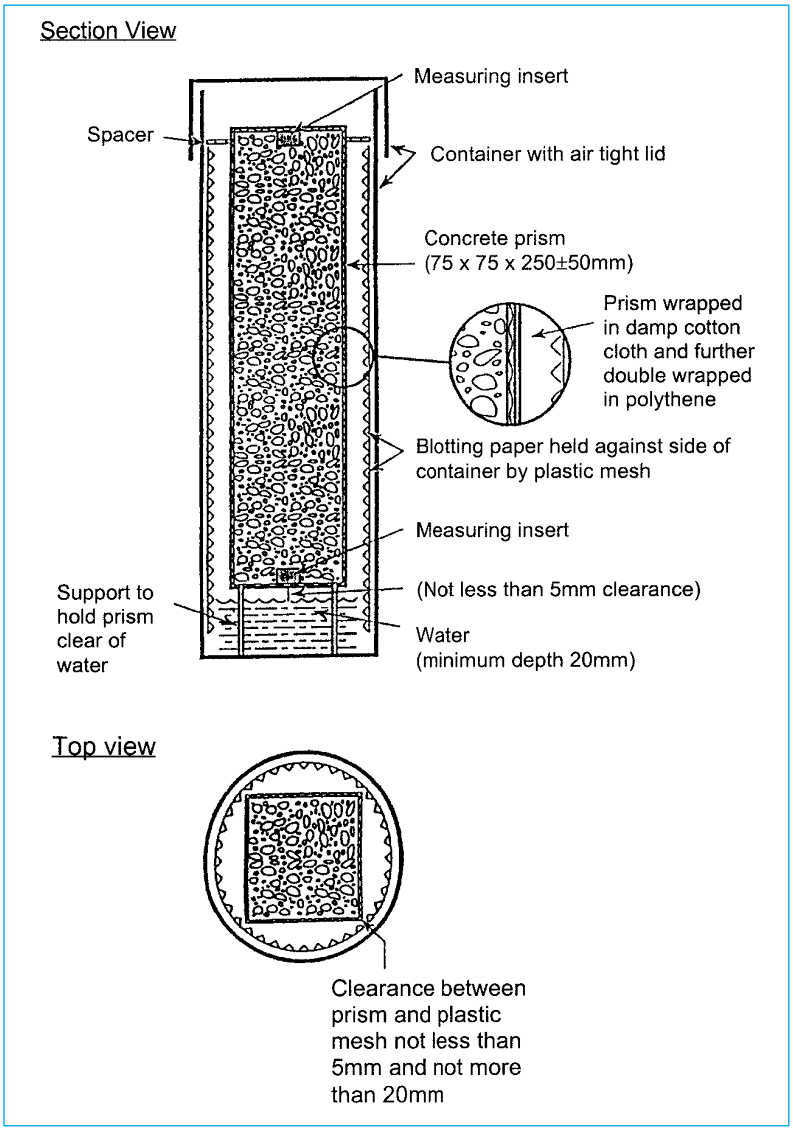

Fig. 1 - Container for Specimen Storage

sodium oxide equivalent (see Note 2). Sodium hydroxide shall be added to the concrete mix water so as to increase the alkali content of the binder to 1.25% ± 0.05% sodium oxide equivalent (see Note 3).

NOTE 2: Suitable reference cements are available from Norcem A.S, R&D Department, 3950 Brevik, Norway (contact Dr K. O. Kjellsen), or from National Council for Cement and Building Materials, Calibration Testing & Quality Control, 34 Km Stone, Delhi-Mathura Road (NH-2), Ballabgarh 121 004, Haryana State, India (contact Mr R. C. Wason).

NOTE 3: Sample calculation for determining the amount of NaOH to be added to the mixing water to increase the alkali content from 1% to 1.25% sodium oxide equivalent:
Cement content of 1 m^3 of concrete = 440 kg
Amount of alkali in concrete = 440 × 0.01 = 4.4 kg
Specified amount of alkali in concrete = 440 × 0.0125 = 5.5 kg
Amount to be added per/m^3 = 5.5 - 4.4 = 1.1 kg sodium oxide equivalent
Conversion factor sodium oxide to sodium hydroxide = 1.921
Amount of sodium hydroxide required = 1.1 × 1.291 = 1.420 kg/m^3.

5.3 Aggregates - Standard aggregate materials test

The aggregate combination shall consist of one or more of the following:
(i) the fine and coarse test aggregates;
(ii) the fine test aggregate combined with a non-reactive coarse aggregate;
(iii) the coarse test aggregate combined with a non-reactive fine aggregate.

The non-reactive fine or coarse aggregate shall have expansions in the accelerated mortar-bar test [1] of less than 0.05% at 14 days (Note 4).

The aggregate fractions shall be combined in mass proportions on a dry basis of 30% fine aggregate (4 to 0 mm), 30% 10 to 4 mm and 40% 20 to 10 mm. However, where the aggregate mass proportions are considered to be inappropriate for attaining suitable workability refer to the Annex (see A5.2).

NOTE 4: This expansion limit is deliberately more restrictive than is generally applied to identify non-reactive aggregates to ensure that the non-reactive reference aggregate has minimal effect on the results of this test.

NOTE 5: If a more precise investigation of the pessimum behaviour is desired, other combinations of the reactive and non-reactive aggregates can additionally be tested (see A5.3 Note A5).

NOTE 6: If an assessment of the aggregate combination to be used in a specified job is needed, the aggregates shall be combined in the proportions and grading specified.

NOTE 7: See A4.1 if aggregates of greater than 20mm particle size are to be tested.

6. CONCRETE MIX DESIGN (see also A6)

Cement content	14 volume %
Free (effective) water content	20 volume %
Coarse aggregate	46 volume %
Fine aggregate	20 volume %
[or aggregate combination specified	66 volume %]

NOTE 8: The free (or effective) water is the water available for hydration of cement and for the workability of the fresh concrete. The total water added to the mix is

the free water plus water absorbed by the aggregate to bring it to a saturated surface dry condition.

NOTE 9: It is important that the mix is sufficiently workable to enable good compaction. With some flaky aggregates the above mix might not be sufficiently workable. If the slump of the concrete is less than 80 mm, a plasticiser (not one combined with an air-entraining agent) should be used. In this case the (small) amount of alkali contributed by the plasticiser should be taken into account in calculating the amount of additional sodium hydroxide to add.

NOTE 10: Volume proportions are specified in order to maintain a constant amount of cement (and hence alkali) per unit volume of aggregate when aggregates of different density are tested. Weight proportions for an aggregate of typical density are given in A6.

7. TEST SPECIMENS

Add the sodium hydroxide to the mixing water before mixing, ensuring all is dissolved before use.

Cast three test prisms from each mix, compacting the concrete into the moulds in two layers of equal depth using mechanical vibration.

Cure at 20 ± 2°C in relative humidity of not less than 90% under moist covers for 24 ± 0.5 hours (see also A4.6).

8. STORAGE AND MEASUREMENT

After demoulding, wrap the prisms in wet cloth and polythene bags as described below and store for 24 hours at 20 ± 2°C until the initial measurement (see also A4.6).

For each prism, cut a piece of the cotton cloth 640 mm long and 10mm wider than the length of the prism. Saturate each cloth with deionised water (typically 80 ml is required for a cloth 260 mm wide) and wrap one piece around the four large faces of each prism in two layers. Place the wrapped prisms into single pieces of the polythene tubing of the same length as the prisms. Smooth each tube around the cloth and secure with stout rubber bands.

NOTE 11: No wrapping is applied to the end faces of the prisms.

Place the wrapped prisms in polythene bags. Pour 5 ml of deionised water over the upper end face of each prism and seal the bags. Place each bagged prism in a storage container, and ensure that it contains deionised water to at least 20 mm depth.

Twenty-four hours after demoulding, remove each prism from its polythene bag, but leave the wrapping and rubber bands undisturbed. Clean the reference studs, measure the initial length (l) of each prism to the nearest 1 mm using a steel rule, weigh the prisms to the nearest ± 5 g (W_o) and take an initial reading on the comparator (C_o) using the Invar® rod to check the length of the measuring apparatus. These and all subsequent measurements to be made at a temperature of 20 ± 2°C (see also A4.6).

Immediately after each measurement, replace the wrapped prism in its polythene bag. Pour 5 ml of deionised water over the upper end of the prism before sealing the bag. Verify that there is at least 20 mm minimum amount of deionised water in the containers and place the bagged prisms inside. Replace and seal the lids and store at 20 ± 2°C until the next measurement (C_7, W_7), which shall be at 7 days after mixing.

After the 7 day measurement, store the containers in a cabinet or room maintained at 38 ± 2°C until required for further measurement. Twenty four hours before making each set of further measurements, remove the prisms from the cabinet or room and allow them to cool at 20 ± 2°C whilst remaining inside the containers.

At the end of periods 2, 4, 13, 26, and 52 weeks after mixing (see Note 12), remove the prisms from their containers, clean the reference studs and take comparator readings on the Invar rod and three prisms. Weigh the prisms to the nearest 5 g.

NOTE 12: Some types of slowly reacting aggregate may not exhibit deleterious expansion after 52 weeks. Depending on local experience, the length of the test may be extended.

9. EXPRESSION AND REPORTING RESULTS

Calculate the increase in length and weight for each prism for each period of measurement from the difference between the initial comparator or weight measurement (C_o, W_o) and the comparator or weight measurement after that period (C_t, W_t). Calculate and report each increase as a percentage of the initial length or weight of the corresponding prism to the nearest 0.01%.

For example, at 52 weeks the percentage length change E52 of a prism is given by:

$$E_{52} = \frac{C_{52} - C_0}{l} \times 100$$

where

C_{52} is the comparator measurement at 52 weeks age,
C_o is the initial comparator measurement of the prism,
and l is the initial length of that prism (in mm).

Also calculate the mean length and weight change of the three prisms for each measurement age to the nearest 0.005%.

For example, at 52 weeks the mean percentage length change mE52 of the three test prisms is given by:

$$mE_{52} = \frac{E_{52/1} + E_{52/2} + E_{52/3}}{3}$$

After the final measurement (see Note 13), the prisms shall be examined and any cracking, gel exudations, warping or other features noted and reported.

The mix design and prism size used, the cement source and alkali content, any alkali additions, the slump of concrete used in the prisms, any plasticiser and any alkali contributed by the plasticiser, shall be reported.

NOTE 13: If the prisms exhibit an average expansion which is judged to be deleterious, a petrographic examination of the interior of the prism which has expanded most should be carried out, together with an examination of the internal crack pattern, to confirm that the cause of the expansion is likely to be an alkali-silica reaction [2].

ANNEX

(comments relate to clauses as numbered in the method)

A4.1 Moulds

The use of other mould sizes (*e.g.* the ISO 1920 size viz 400 × 100 × 100 mm) may necessitate reconsideration of the expansion limits.

A4.5 Specimen storage

There is contradictory information on the advantages of wrapping or not wrapping specimens and the use of containers containing single or multiple specimens. In order to maximise reproducibility and the chances of maintaining a high and uniform humidity, the wrapping procedure and the use of containers for single specimens is specified in this method. It has been found that wrapping of specimens typically produces higher expansions than equivalent unwrapped specimens.

A4.6 Casting and measurement environment

Cooling to a standard temperature is necessary both to obtain reproducible results and to protect the health of the operator. In tropical countries, however, it may be necessary to allow the casting and measurement to be carried out in a room maintained at 27 ± 2°C and not less that 65 ± 5% RH. This may however necessitate reconsideration of the expansion limits.

A5.3 Aggregates - Standard aggregate materials test

Where the shape and texture of the aggregate renders a 70/30 ratio of coarse to fine aggregate unworkable, the ratio may be adjusted on an absolute volume basis, but the maximum content of coarse aggregate with which full compaction can be achieved should be employed.

NOTE A4: With some reactive aggregates it has been found that there is a proportion of reactive constituents in the aggregate that leads to a maximum expansion. This proportion is called the 'pessimum' content, and the relationship between expansion and reactive constituents content is called the 'pessimum behaviour' of the reactive aggregate.

A6. CONCRETE MIX DESIGN

For aggregates with a 'normal' density (approximately 2.6 to 2.75), the weight proportions below will give a close approximation to the volume proportions in clause 6:

cement content	440 kg/m^3
free (effective) water content	200 kg/m^3
coarse aggregate	1247 kg/m^3
fine aggregate	535 kg/m^3.

In some countries there are less reactive aggregate combinations which are identified as only marginally reactive with the standard mix but which have proved reactive in field concrete. Examples are flint sand/limestone coarse aggregate combinations in the UK, and flint/chert in limestone in Italy. For such aggregates, a test concrete with higher alkali content may be necessary. An example is the mix used in the BS method [3]:

cement content	700 kg/m^3
free (effective) water content	228 kg/m^3
coarse aggregate	1010 kg/m^3
fine aggregate	430 kg/m^3.

TC 106-3 REFERENCES

[1] RILEM Recommendation TC 106-2 'Detection of potential alkali-reactivity of aggregates - The ultra-accelerated mortar-bar test', *Mater. Struct.* (in this paper).

[2] Report of a Working Party, 'The diagnosis of alkali silica reaction' (British Cement Association, 2nd Edition, 1992), BCA, Slough (now Crowthorne), UK.

[3] BS 812:Part 123:1999, 'Testing aggregates - Method for determination of alkali-silica reactivity - Concrete prism method', British Standards Institution, London, UK. (was DD 218).