

# **THE USE OF ACCELERATED MORTAR BAR TEST METHODS FOR ASSESSMENT OF ALKALI-AGGREGATE REACTIVITY OF AGGREGATE IN HONG KONG**

**GEO REPORT No. 145**

**K.K. Liu & W.H. Tam**

**GEOTECHNICAL ENGINEERING OFFICE  
CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT  
THE GOVERNMENT OF THE HONG KONG  
SPECIAL ADMINISTRATIVE REGION**

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## PREFACE

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R.K.S. Chan  
Head, Geotechnical Engineering Office  
July 2004

## FOREWORD

This report briefly describes the types and mechanisms of the alkali-aggregate reaction (AAR). It also covers the use of different accelerated mortar bar test (AMBT) methods by the Public Works Central Laboratory (PWCL) of the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), for assessing the AAR potential of aggregate in Hong Kong and the conclusions and recommendations drawn.

Mr. W. H. TAM and Dr. W. C. LAU organised the AMBT and analysed the results under the supervision of Mr. K. K. LIU. The technical staff in the Concrete Unit of the PWCL conducted the AMBT. Mr. LIU prepared a first draft of this report, which was later finalised by Mr. Y. H. CHAK. Their contributions are gratefully acknowledged.



(B.N. LEUNG)

Chief Geotechnical Engineer/Materials

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## 1. INTRODUCTION

Good quality concrete should be of adequate strength and durable. A judicious choice of components in concrete in the right proportions and proper placing and adequate curing of concrete are important for achieving the required strength and durability. The alkali content of cement, which is important to the strength development of concrete, may however affect its durability. A typical alkali-aggregate reaction (AAR) occurs when the alkali in concrete reacts with some deleterious minerals in the aggregate, causing expansion and cracking of the concrete.

This report aims to introduce to readers briefly the types and mechanisms of the AAR. It also covers the use of different accelerated mortar bar test (AMBT) methods by the Public Works Central Laboratory (PWCL) of the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), for assessing the AAR potential of aggregate in Hong Kong and the conclusions and recommendations drawn.

## 2. ALKALI-AGGREGATE REACTION IN CONCRETE

### 2.1 Types and Mechanisms of AAR

AAR takes place in concrete when alkali in concrete, or from an external source, reacts with certain aggregate to form products that deleteriously expand, which may result in severe cracking of the concrete. There are three types of AAR, namely alkali-silica reaction, alkali-silicate reaction and alkali-carbonate reaction. The mechanisms of these different types of AAR are described in Table 1. Alkali-silica reaction is the only type of AAR that has been reported to have occurred in Hong Kong.

### 2.2 Conditions and Sources of AAR

In order for AAR to take place in concrete, three conditions must be satisfied:

- (a) the presence of alkali,
- (b) the presence of reactive aggregate in concrete, and
- (c) the presence of water.

The extent of AAR induced deterioration of concrete and the rate at which it occurs are affected by a number of factors, which can generally be grouped as follows:

- (a) the reactivity of the siliceous material,
- (b) the total alkali content of concrete, and
- (c) the supply of moisture.

The alkali in concrete may come from different constituent materials introduced into the concrete, e.g. cement, pozzolana, aggregate and admixtures or from other sources external to the concrete, e.g. de-icing salts (see Table 2).

### 2.3 Occurrence of AAR in Hong Kong

Although AAR has been known to be a problem in many parts of the world, it was not diagnosed in Hong Kong until 1991 (Wong & Koirala, 1992; Irfan, 1994). The Standing Committee on Concrete Technology (SCCT), which was formed to co-ordinate inter-departmental efforts in resolving problems related to concrete technology, became aware of a number of concrete structures in Hong Kong that showed signs of map cracking. Consequently, an AAR sub-committee of SCCT was set up in 1991 to coordinate all investigative and research efforts related to AAR in concrete. The sub-committee issued a technical circular (Works Branch Technical Circular No. 5/94 (Works Branch, 1994)) which recommended limiting the alkali content in concrete to  $3 \text{ kg/m}^3$  to safeguard concrete against AAR.

As requested by the SCCT, the PWCL, with the assistance of the Planning Division of the Geotechnical Engineering Office, has investigated a number of suspected AAR cases in Hong Kong (Wong & Koirala, 1992; Tse & Gilbert, 1994; Gilbert, 1995; Sewell & Campbell, 2001). The investigation also covered the assessment of the AAR potential of aggregate from a number of quarries in Hong Kong and Mainland China using the AMBT methods (see Section 4).

## 3. METHODS OF ASSESSMENT FOR ALKALI-AGGREGATE REACTIVITY

### 3.1 Petrographic Examination

Petrographic examination of hardened concrete is a useful tool for the identification of the mineralogy in aggregate, composition of cement paste and texture of concrete for the purpose of assessing the presence of or potential for AAR. The standard method for such an examination is given in ASTM C295-98 (ASTM, 1998) and RILEM AAR-1 (RILEM, 2001a (in draft)).

The general procedures for identification of AAR involve an examination of polished slabs with the naked eye and under a binocular microscope, followed by a detailed examination of thin sections under a polarizing microscope. The examination of polished surfaces of concrete can identify the size range, shape and type of aggregate and the unusual features in aggregate, such as the presence of foliation, strained quartz, evidence of recrystallization and/or mineralization. In addition, obvious deleterious effects such as cracking, bleeding, infilling of voids and carbonation can also be delineated. In thin sections, the presence of gel filling cracks through the cement paste, across grain boundaries and on the margins of the aggregate fragments are the characteristic features of AAR.

### 3.2 Accelerated Mortar Bar Test (AMBT) Methods

Oberholster & Davies (1986) of the National Building Research Institute (NBRI) in South Africa first developed the AMBT method. The development of all subsequent national or international standard AMBT methods was largely based on the NBRI method. In 1993 the Public Works Laboratories (PWL) started to develop its own method, namely the PWL CON 5.5 method (PWL, 1999), due to the need to investigate the AAR problems in Hong Kong in the early 1990s' and as there were no national and international standard AMBT methods published at that time. The American standard method ASTM C1260 (ASTM, 1994a) and Canadian



standard method CSA A23.2-25A (CSA, 1994a) for AMBT were subsequently issued in 1994. The British Standards Institution published its draft AMBT method DD249 (BSI, 1999a (in draft)) in 1999. The RILEM (a French acronym for the International Union of Laboratories and Experts in Construction Materials, Systems and Structures founded in 1947) published its AMBT method RILEM AAR-2 (RILEM, 2000a) in 2000.

The procedures specified in the above AMBT methods are generally similar, although there are minor variations between them. They all involve the preparation of a set of a minimum of three mortar bars of size 25 x 25 mm and 250 - 300 mm long for each test. Mortar is prepared by mixing aggregate of maximum size up to 4-5 mm with water and cement that contains the specified alkali content. It is then compacted into a steel mould and stored for about 24 hours. It is subsequently demoulded and cured by immersing it in water at about 80°C for another 24 hours. An initial reading is taken of the length of the mortar bar so formed. It is then immersed in sodium hydroxide solution, which is maintained at a temperature of about 80°C. Thereafter the bar is taken out of the solution at certain time intervals and further readings are taken. A comparison of the different AMBT methods is given in Table 3.

It should be noted that the RILEM method uniquely specifies the use of cement with specific surface area greater than 450 m<sup>2</sup>/kg and a minimum alkali content of 1.0%. The method mentions that suitable reference cement that meets these requirements is available from Norway (the 'Norcem' cement) or the National Council for Cement and Building Materials in India. The draft BS standard method DD 249: 1999 also specifies similar requirements for the cement to be used.

The criteria for the classification of the potential deleteriousness of the aggregate expansion measured using the AMBT methods are specified in the ASTM C1260 (ASTM, 1994a), CSA A23.2-25A (CSA, 1994a) and draft BS standard method DD249: 1999 (BSI, 1999a (in draft)) (see Table 4). However, no similar criteria are specified in the RILEM AAR-2 (see note 6 in Table 4 for advice by RILEM on this subject) and PWL CON 5.5 methods.

### 3.3 Other Assessment Test Methods

Besides the petrographic examination and the AMBT method, there are other test methods for the assessment of AAR potential, namely the concrete prism test (CPT) and the accelerated concrete prism test (ACPT).

For the CPT, concrete prisms of 75 x 75 mm cross-section are prepared with the aggregate to be tested. They are then stored in humid conditions and at a temperature of about 38°C for 12 months. Measurements are made at periodic intervals to determine any expansion that has occurred. Several national and international standard methods exist for this test (see Table 5). However, little is known regarding their use in Hong Kong. RILEM is the only standards body who is developing a standard method for the ACPT (RILEM AAR-4 method (RILEM, 2001b (in draft)), which aims to elevate the temperature to 60°C and relative humidity close to 100% for the storage of the concrete prisms and to complete the test within 20 weeks.

ASTM has also produced a standard mortar bar test method, ASTM C227 (ASTM, 1997), and a standard chemical method, ASTM C289 (ASTM, 1994b), for the assessment of AAR. However, the mortar bar test method takes a year to complete and is now commonly

replaced by the AMBT methods. The chemical method, although can be completed within 24 hours, is not very reliable. Moreover, the results of this chemical test method may not be correct for aggregate containing carbonates of calcium, magnesium or ferrous iron, such as calcite, dolomite, magnesite or siderite, or containing silicates of magnesium such as antigorite (serpentine). In all cases, further confirmatory testing using other methods is required.

A summary of the currently available standard test methods for assessing AAR potential is given in Table 5. The results of the petrographic examination, AMBT, CPT and ACPT methods are indicative only, and whenever possible they should be correlated with field performance if long-term performance of a concrete structure with respect to AAR is to be assessed.

#### 4. ASSESSMENT OF AAR POTENTIAL OF AGGREGATE IN HONG KONG USING AMBT METHODS

##### 4.1 Scope of Tests Conducted

Since 1996, the PWCL has carried out a series of AMBT to assess the AAR potential of a comprehensive range of local aggregate as well as aggregate imported from Mainland China. The aggregate tested included granite aggregate, aggregate of volcanic ash tuff and aggregate which has been known to be highly alkali-aggregate reactive. The aggregate from the SPRATT Quarry in Canada (a reference aggregate) was also included in the testing programme for reference purposes. The testing of the aggregate was repeated using different AMBT methods, namely the ASTM C 1260, CSA A23.2-25A, PWL CON 5.5 and RILEM AAR-2 methods. Besides assessing the AAR potential of the aggregate from different origins, the testing programme also aimed to compare the results obtained using different AMBT methods.

##### 4.2 Results and Discussion

The results of the series of AMBT are summarised in Table 6 and presented in Figure 1. As can be seen, the percentage expansions of mortar bars of granite aggregate are mostly below 0.1%. According to the criteria recommended by national or international standards for interpretation of the AMBT results (see Table 4), these aggregates should be considered as innocuous with respect to AAR. The results of the Aggregate Type HK4 and Aggregate Type C10 of volcanic ash tuff and the reference aggregate from the Spratt Quarry (Canada) exceed 0.2%. These aggregates should be considered as potentially deleteriously reactive with respect to AAR. The expansion of the Aggregate Type C9 of granodiorite exceeds 0.1% but below 0.2%, the alkali aggregate reactivity of which should be considered as inconclusive. The expansion of the aggregate from the SPRATT Quarry was found to be the greatest (> 0.4%).

As can be seen from Figure 1, for expansions below 0.2% the RILEM AAR-2 method tends to give higher expansion values than the other methods. This may be due to the higher alkali content of the cement (viz. 1% minimum as compared with 0.8-0.9% in other methods) and the stringent requirement for high specific surface area of the cement (> 450 m<sup>2</sup>/kg) specified for use in this method. However, the measurement of higher expansion by this method is not observed when expansion exceeds 0.2%. This may be due to the possibility that for highly reactive aggregate, the effect of the buffer solution (i.e. the 1 M NaOH) becomes dominant and outweighs that of the higher alkali content of the cement.

The results obtained using the RILEM AAR-2 method would likely be more repeatable, as only the reference cement, which is produced at a highly consistent standard, can meet the stringent requirements in respect of alkali content and specific surface area of the cement specified for use in this method. The BS method DD249 (BSI, 1999a, (in draft)) also specifies similar requirements for the cement. RILEM is currently the only standards body that is preparing a complete series of tests (petrographic examination, AMBT, CPT and ACPT) for the assessment of AAR potential (see Table 5). It would be useful to adopt the RILEM methods as the standard methods, when they are all finalised. This is because a complete series of test methods for assessment of AAR potential will then be available and a full assessment for AAR potential can be conducted, if needed. Therefore, it is recommended to adopt the RILEM AAR-2 method as the standard AMBT method for use in Hong Kong. The SCCT has endorsed this recommendation. It has also endorsed a recommendation put forward by PWCL that when using the RILEM AAR-2 method, 0.1% expansion is accepted as the limit below which aggregate is considered to be innocuous. This is in line with most of the internationally accepted practices (see Table 4).

The results obtained using the PWL CON 5.5 method were correlated with those obtained using the ASTM C1260 and CSA A23.2-25A methods, and the results are shown in Figures 2 and 3 respectively. As can be seen, the results obtained using the PWL CON 5.5 method are in better agreement with those obtained using the ASTM method. Therefore, in case interpretation of results previously obtained by the PWL CON 5.5 method is needed, the criteria adopted by the ASTM method for the classification of potential deleterious expansion of aggregate (see Table 4) can be adopted.

## 5. CONCLUSIONS AND RECOMMENDATIONS

Based on the work done by the PWCL as described in this report, the following conclusions and recommendations can be made:

- (a) Based on the results of the series of AMBT conducted by the PWCL as described in this report, the expansions of nearly all aggregates commonly adopted for use in concrete production in Hong Kong were found to be below 0.1%.
- (b) The results obtained by the PWL CON 5.5 method show better agreement with those obtained by the ASTM C1260 method than the CSA A23.2-25A method. Accordingly, the criteria for the classification of potential deleterious expansion of aggregate recommended in the ASTM method can be adopted as those for the PWL CON 5.5 method in case interpretation of results previously obtained using the PWL CON 5.5 method is needed.
- (c) Where the AMBT method is to be adopted for assessing the AAR potential of aggregates included in concrete production in Hong Kong, the RILEM AAR-2 method is recommended to be adopted as the standard method, as a set of clear and consistent conditions is specified for testing

using this method (e.g. the use of cement of minimum specific surface area and alkali content).

- (d) For assessing the AMBT results, most national and international standards recommend adopting 0.1% as the expansion limit below which aggregate is considered to be innocuous with respect to AAR (the “innocuous” limit). Only the Canadian standard recommends adopting a “innocuous” limit of 0.15%. It is therefore recommended that the 0.1% expansion measured using the RILEM AAR-2 method be adopted as the “innocuous” limit at this stage. Further work is however needed to be carried out to deal with the aggregates with expansion exceeding this limit.
- (e) For aggregates that are found to exceed the 0.1% expansion limit when tested using the RILEM AAR-2 method, it is also recommended that further evaluation of the AAR potential of aggregates is permitted by re-testing using other national or international AMBT methods. The results should then be compared with the corresponding “innocuous” limits adopted for use with these methods. The AAR potential of the aggregates should be confirmed by such tests in conjunction with other methods such as petrographic examination. Whether the above recommended 0.1% expansion limit could be relaxed to a higher value will be reviewed when more data are obtained in future.
- (f) The RILEM’s methods for petrographic examination, AMBT, CPT and ACPT (i.e. RILEM AAR-1 to -4) is the only complete series of test methods produced by the same standards body that presents a holistic approach to the assessment of AAR potential. They should therefore be considered for use as the basis of a framework for screening aggregate for AAR potential in Hong Kong.
- (g) The RILEM’s methods for CPT and ACPT (i.e. RILEM AAR-3 and -4) should be tried out using local aggregates.

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Table 1 - Types and Mechanisms of Alkali-aggregate Reactions

Type of AAR	Mechanism of Reaction
Alkali-silica reaction	<p>The alkali-silica reaction takes place in concrete when the alkali, mainly sodium and potassium oxides (<math>\text{Na}_2\text{O}</math> and <math>\text{K}_2\text{O}</math>) in concrete, reacts with the reactive silica in aggregate. The chemical reaction begins with the attack of the reactive silica by the alkaline oxides. The reaction would lead to the formation of calcium-rich alkali-silica gel, which has a strong affinity for water. The gel absorbs water and expands, exerting pressure in all directions and forming cracks through the aggregate and cement paste. Some of the gel may ultimately leach out through the cracks. The expansion of the gel can cause deterioration of the concrete which may take 2 to 25 years before it can develop to a significant extent in the field, depending on the reactivity of the aggregate, the total alkali content in concrete and the exposure conditions.</p>
Alkali-silicate reaction	<p>The alkali-silicate reaction is somewhat similar to the alkali-silica reaction, except that the reactive constituents in the aggregate are not the free silica but the silicate which exists in a combined and fine-grained form - phyllosilicates. The phyllosilicates, if not in a fine-grained form, are not very reactive. Alkali-silicate reaction has not been reported to have occurred in Hong Kong.</p>
Alkali-carbonate reaction	<p>The alkali-carbonate reaction occurs in concrete when alkali comes into contact with clay containing dolomitic limestone. The alkali reacts with the reactive silica in dolomite, causing dolomite to break down into brucite and calcite. This process is known as dedolomitisation. As a result of the dedolomitisation, cracks would be formed on the aggregate, leading to ingress of moisture. This would then cause the clay to swell, disrupt the aggregate and finally crack the concrete. Alkali-carbonate reaction has not been reported to have occurred in Hong Kong.</p>



Table 2 - Possible Sources of Alkali in Concrete

(a) Cement	Cement could be a major source of alkali as it contains alkaline oxides ( $\text{Na}_2\text{O}$ and $\text{K}_2\text{O}$ ).
(b) Pozzolana	Pozzolana is a common cementitious material. The siliceous or aluminous materials contained in pozzolana may react with lime ( $\text{CaO}$ ) at ambient temperature to form cementitious compounds. Alkali is then released during the process.
(c) Aggregate	Feldspar, mica, glassy rock and glass in aggregate may release alkali in concrete. Marine sand may contain traces of sodium chloride which, if not washed thoroughly, can introduce a significant amount of alkali in concrete.
(d) Admixture	Admixture (e.g. accelerators, retarders, water reducers, superplasticizers and air entraining agents) may contain sodium and potassium compounds which can increase the alkali content of concrete.
(e) De-icing salts	In cold areas, the use of de-icing salts containing sodium ions may increase the alkali content of concrete.
(f) External sources	Soils containing alkali may also increase the alkali content of the concrete that comes into contact with them.

Table 3 - Comparison of Different Accelerated Mortar Bar Test Methods

	PWL CON 5.5	ASTM C1260 (94)	CSA A23.2-25A(94)	RILEM AAR-2	DD 249 : 1999 <sup>(1)</sup>
Size of specimen	25 x 25 x 285 mm	25 x 25 x 285 mm	25 x 25 x 285 mm	25 x 25 x 285 mm <sup>(2)</sup>	25 x 25 x 250 mm
Number of bars	3	≥3	≥3	≥3	≥4
Laboratory conditions	20 ± 2°C; RH ≥ 65%	20°C to 27.5°C; RH ≥ 50%	20°C to 26°C; RH ≥ 50%	20 ± 2°C; RH ≥ 50%	20 ± 5°C; RH ≥ 50%
Temp. of water used	20 ± 2°C	23 ± 1.7°C	23 ± 2°C	20 ± 2°C	20 ± 5°C
Alkali content of cement	0.85 ± 0.05%	Requirement not specified	0.9 ± 0.1%	Min. 1.0%	1 ± 0.1%
Specification of cement	Locally available cement, preferably with alkali content >0.55%	Complies with specification C150; autoclave expansion < 0.2%	Portland Cement (Type 10) specified in CAN/CSA-A5	Specific surface > 450 m <sup>2</sup> /kg; autoclave expansion < 0.2 or MgO soundness = 0 mm	Specific surface > 450 m <sup>2</sup> /kg; autoclave expansion < 0.2 or MgO soundness = 0 mm
Aggregate size distribution					
10%	4.75 mm to 2.36 mm	4.75 mm to 2.36 mm	5 mm to 2.5 mm	4 mm to 2 mm	5 mm to 2.36 mm
25%	2.36 mm to 1.18 mm	2.36 mm to 1.18 mm	2.5 mm to 1.25 mm	2 mm to 1 mm	2.36 mm to 1.18 mm
25%	1.18 mm to 600 µm	1.18 mm to 600 µm	1.25 mm to 630 µm	1 mm to 500 µm	1.18 mm to 600 µm
25%	600 µm to 300 µm	600 µm to 300 µm	630 µm to 315 µm	500 µm to 250 µm	600 µm to 300 µm
15%	300 µm to 150 µm	300 µm to 150 µm	315 µm to 160 µm	250 µm to 125 µm	300 µm to 150 µm
Amount of water required	Determined by flow value	Water/Cement ratio = 0.47	Water/Cement ratio = 0.44 for natural fine aggregate or 0.50 for crushed coarse aggregate	Water/Cement ratio = 0.47	Water/Cement ratio = 0.47
Flow value required	105 - 120%	Not mentioned	Not mentioned	105 - 120% (Superplasticizer may be added)	Optional
Mixing of mortar and time required for the mixing	Mixing of mortar for 2½ min in mixer, fill mould in 2 equal layers and compacted with tamper	Mixing in accordance with ASTM C305, fill mould within 2¼ min. in 2 equal layers after mixing	Mixing in accordance with ASTM C305, fill mould within 2¼ min. in 2 equal layers after mixing	Mixing in accordance with EN 196-1 ≤ 3 minutes for moulding after completion of mixing in 2 equal layers	Mixing, filling mould, compacted, finished and cured in accordance with BS 4551-1:1998, Clause 12.2.6
Conditions and duration of storage of specimens in mould	20 ± 2°C; RH ≥ 95% 24 ± 2 hours	23 ± 1.7 °C; RH ≥ 95% for 24 ± 2 hrs	23 ± 2°C; RH > 95% for 24 ± 2 hrs	20 ± 1°C; RH ≥ 90% 24 ± 2 hours	20 ± 5°C, RH > 95% for 24 ± 2 hrs
Initial curing after demoulding	Immersed in distilled water, then raise water temp. from 20 to 80 °C over a period of 4 ± 0.5 hr, maintain water temp at 80 ± 2° C for 20 ± 0.5 hr	Immersed in tap water at room temp. and placed in oven or water bath at 80 ± 2° C for 24 hrs	Immersed in tap water at room temp. and placed in oven or water bath at 80 ± 2° C for 24 hrs	Immersed in distilled water container at room temp. and placed in oven at 80 ± 2° C for 24 hrs	Immersed in 20 ± 5°C distilled water container and placed in oven at 80 ± 2° C for 24 ± 2 hrs
Volume ratio of NaOH solution to specimen	Min. 4 times vol. of mortar bars	4 ± 0.5 times vol. of mortar bars	4 ± 0.5 times vol. of mortar bars	4 ± 0.5 times vol. Of mortar bars	4.8 times vol. of mortar bars
Conditions of storage for specimens pending expansion measurement	1M NaOH @ 80° ± 2°C	1N NaOH @ 80° ± 1°C	1N NaOH @ 80 ± 2°C	1M NaOH @ 80° ± 2°C	1M NaOH @ 80° ± 2°C
Measurement frequency after casting	Readings taken at 2, 7, 9, 14 & 16 days	Readings taken at 2 days & at least 3 intermediate readings before final reading at 16 days, and at least one reading was taken weekly if the measurement is to be continued further	Readings taken at 2 days & at least 3 intermediate readings before final reading at 16 days, and at least one reading was taken weekly if the measurement is to be continued further	Readings taken at 2, 3 days & at least 3 intermediate readings taken before final reading at 16 days	Readings taken at 2, 3, 9 and 16 days
Time within which expansion measurements should be taken after a bar specimen is taken out of the NaOH solution	20 sec	15 ± 5 sec	15 ± 5 sec	15 sec	15 ± 5 sec
Storage period	Not Specified	16 days after casting or longer	16 days after casting or longer	16 days after casting or longer	Not specified
Compliance criteria	Not specified	Criteria specified, see Table 4	Criteria specified, see Table 4	Not specified	Criteria specified, see Table 4
Notes: (1) The DD249 is a draft British Standard. (2) Length in the range of 250-300 mm is also acceptable. Other bar size (e.g. 40 x 40 x 160 mm) can also be used as an alternative option subject to a suitable conversion factor.					

Table 4 - Criteria for Classification of Potential Deleterious Expansion of Aggregate Recommended in Various AMBT Methods

AMBT Method	Days Immersion in NaOH Solution	Expansion Limit (%)	Classification
NBRI	14	$\leq 0.10$	Innocuous
		$> 0.10 < 0.25$	Potentially reactive, slowly expanding
		$\geq 0.25$	Potentially reactive, rapidly expanding
ASTM C 1260		$< 0.10$	Innocuous <sup>(1)</sup>
		0.10 to 0.20	Innocuous as well as potentially deleteriously reactive <sup>(2)</sup>
		$> 0.20$	Potentially deleteriously reactive
CSA A23.2-25A		$< 0.15^{(3)}$	Innocuous <sup>(4)</sup>
DD 249: 1999		$< 0.10$	Innocuous
		0.10 to 0.20	Inconclusive (other assessment required)
		$> 0.20$	Potentially expansive
<p>Notes:</p> <p>(1) ASTM notes that some granitic gneisses and metabasalts have been found to be deleteriously expansive in field performance even though their expansion in AMBT is less than 0.10% at 14 days after immersion in NaOH. With such aggregate, ASTM recommends that prior field performance should be investigated. In the absence of field performance data, mitigation measures (such as the use of low-alkali Portland cement) should be taken.</p> <p>(2) ASTM considers it particularly important to obtain supplementary information through petrographic examination, examination of the tested specimens and field service records. It may also be useful to take further expansion readings until 28 days after immersion in NaOH solution.</p> <p>(3) CSA recommends a lower limit (0.1%) for some siliceous limestones.</p> <p>(4) CSA notes that several types of aggregate with expansions <math>&gt; 0.15\%</math> have given satisfactory field performance and it recommends further testing to be conducted.</p> <p>(5) No similar criteria are specified in the PWL CON 5.5 method (see Section 5.2 of this Report).</p> <p>(6) No similar criteria are specified in the RILEM AAR-2 method. However, on the basis of trials carried out by RILEM on aggregate combinations of known field performance from various parts of the world, RILEM considered that results in the test of less than 0.10% were likely to indicate non-expansive materials, whilst results exceeding 0.20% were found to indicate expansive materials (draft ‘Outline Guide to the Use of RILEM Methods in Assessments of Aggregates for AAR Potential’, dated 22 April 2001 issued by RILEM).</p>			

Table 5 - Standard Test Methods for Assessment of Alkali-aggregate Reactions

Test Method	RILEM	ASTM Standard	Canadian Standard	Hong Kong Test Specification	British Standard
Petrographic Examination	AAR-1 (RILEM, 2001a (in draft))	ASTM C295 (ASTM, 1998)	---	---	BS 812:Part 104 (BSI, 1994)
Accelerated Mortar Bar Test (AMBT)	AAR-2 (RILEM, 2000a )	ASTM C1260 (ASTM, 1994a)	CSA A23.2-25A (CSA, 1994a)	PWL CON5.5 (PWL, 1999)	DD 249: 1999 (BSI, 1999a (in draft))
Concrete Prism Test (CPT)	AAR-3 (RILEM, 2000b )	ASTM C1293 (ASTM, 2001)	CSA A23.2-14A (CSA, 1994b)	---	BS 812:Part 123 (BSI, 1999b)
Accelerated Concrete Prism Test (ACPT)	AAR-4 (RILEM, 2001b (in draft))	---	---	---	---
Mortar Bar Test		ASTM C227 (ASTM, 1997)			
Chemical Method		ASTM C289 (ASTM, 1994b)			

Table 6 - Percentage Expansion of Mortar Bars Prepared Using Aggregates From Different Sources and Measured by Different Test Methods

Type of Aggregate	Mean Percentage Expansion of Mortar Bars After 14 days of Testing (%)			
	PWL CON5.5	ASTM C1260 (94)	CSA A23.2-25A (94)	RILEM AAR-2
Type C1, China (Granite)	0.017	0.016	0.016	0.029
Type C2, China (Granite)	0.019	0.019	0.019	0.039
Type C3, China (Granite)	0.020	0.025	0.024	0.039
Type C4, China (Granite)	0.023	0.024	0.021	0.027
Type C5, China (Granite)	0.026	0.033	0.025	0.041
Type HK1, Hong Kong (Granite)	0.026	0.016	0.036	0.052
Type C6, China (Granite)	0.029	0.030	0.026	0.052
Type C7, China (Granite)	0.044	0.050	0.047	0.073
Type C8, China (Diorite)	0.059	0.064	0.055	0.072
Type HK2, Hong Kong (Granite)	0.068	0.084	0.078	0.061
Type HK3, Hong Kong (Granite)	0.074	0.090	0.076	0.108
Type C9, China (Granodiorite)	0.184	0.137	0.135	0.186
Type C10, China (Ash tuff)	0.298	0.285	0.224	0.217
Type HK4, Hong Kong (Ash tuff)	0.350	0.334	0.359	0.309
Spratt (SC), Canada (Ash tuff)	0.458	0.421	0.423	0.464

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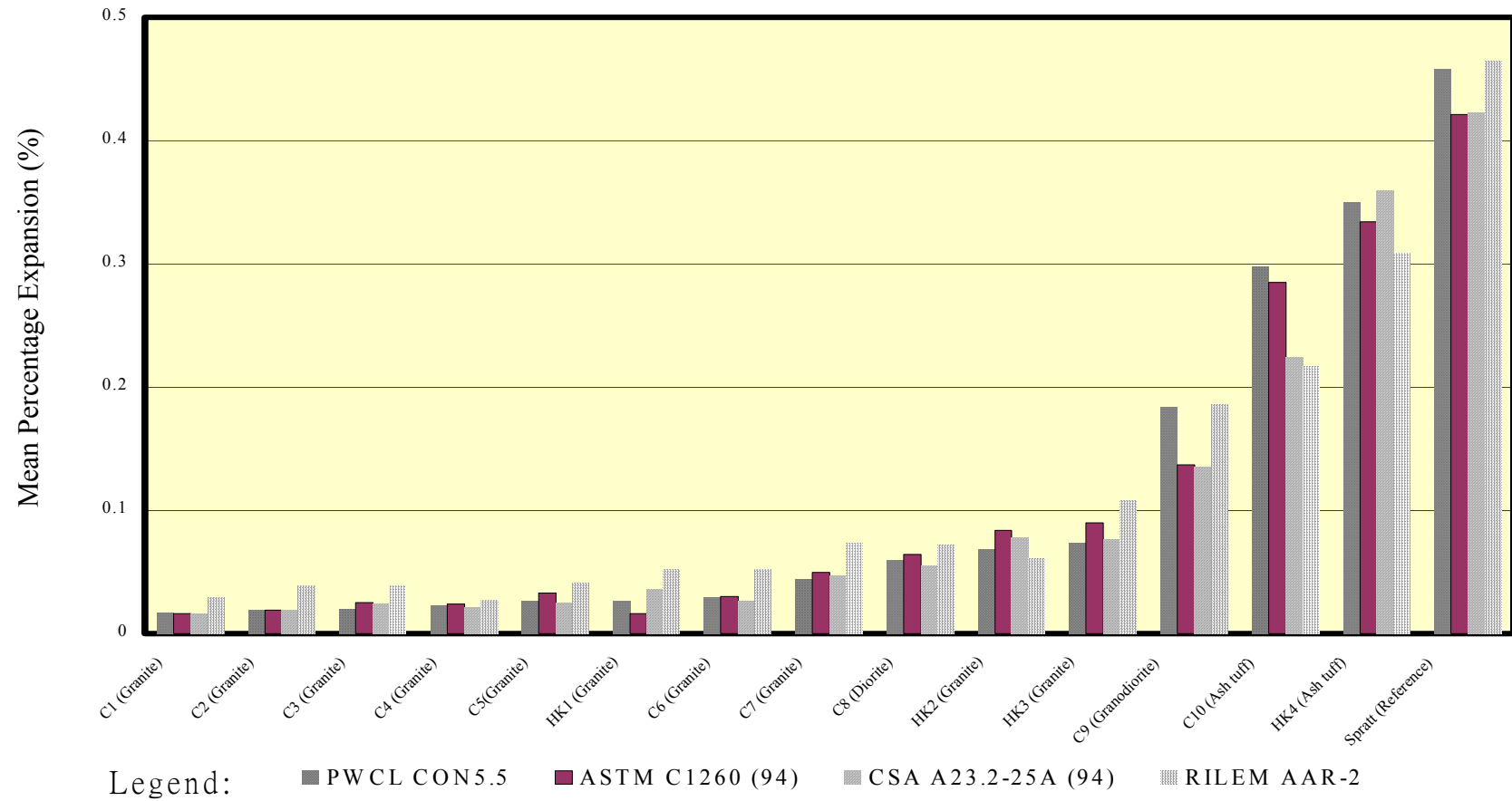


Figure 1 - Percentage Expansion of Mortar Bars Prepared Using Aggregates From Different Sources and Measured by Different Test Methods

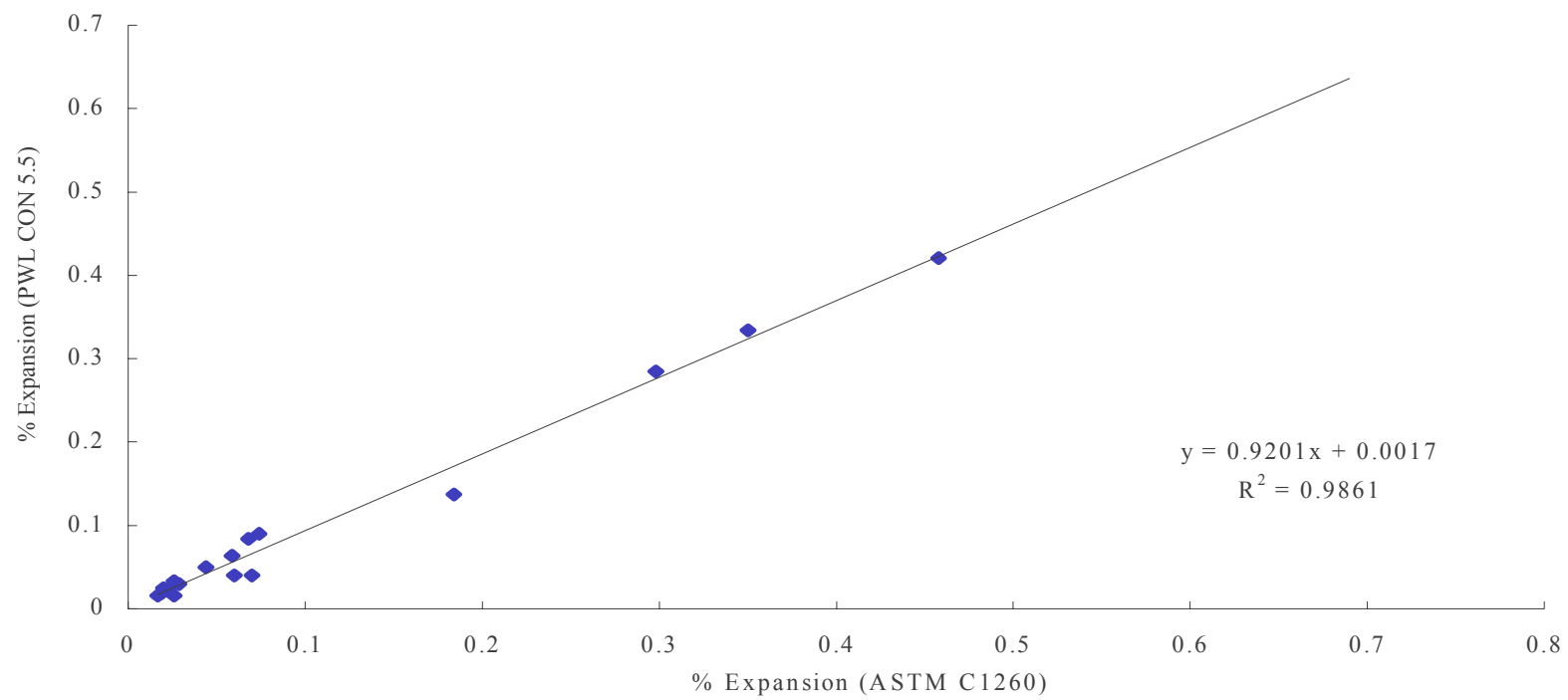


Figure 2 - Correlation between the Results Obtained by the PWL CON 5.5 Method and Those by the ASTM C 1260 Method



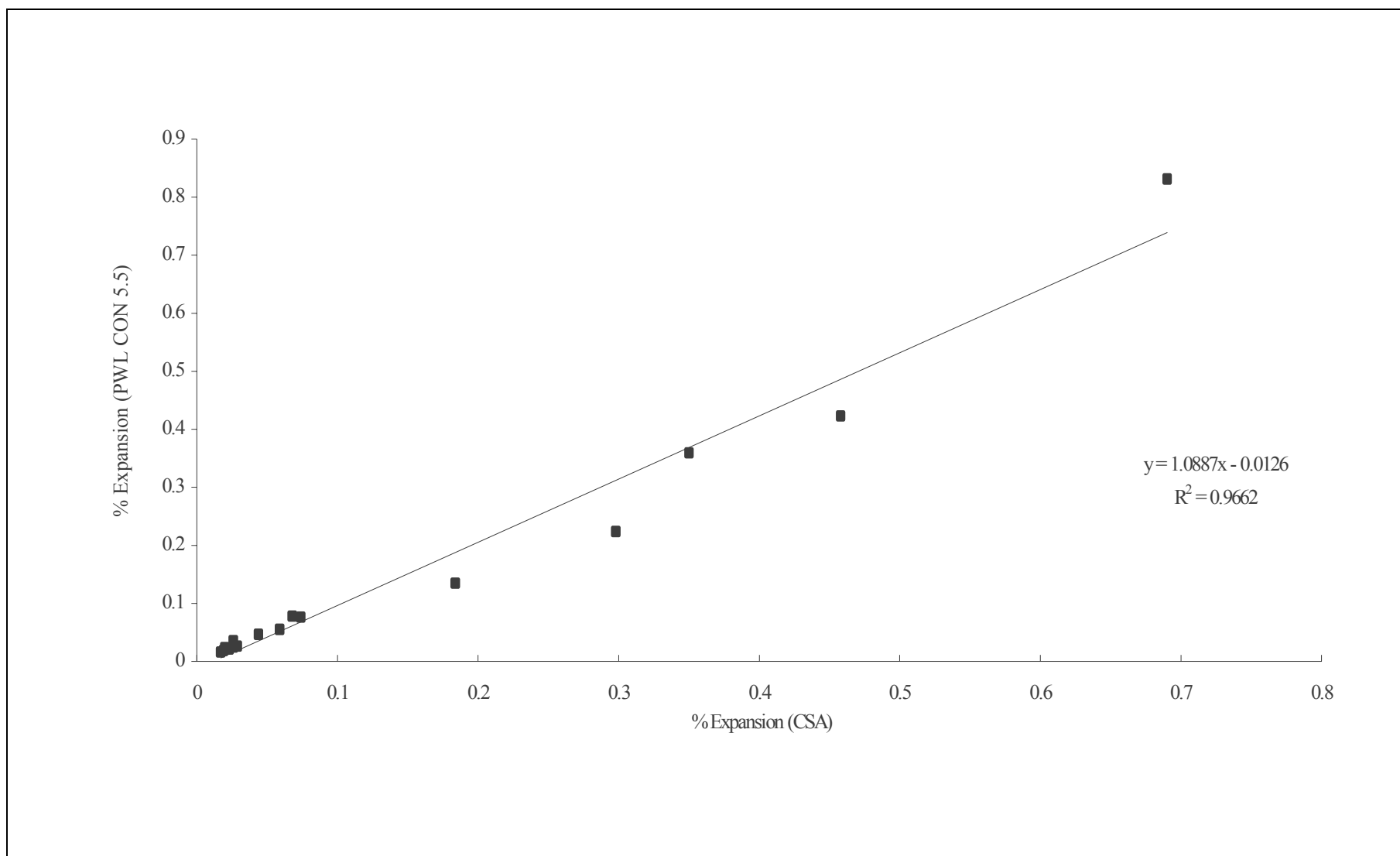


Figure 3 - Correlation between the Results Obtained by the PWL CON 5.5 Method and Those by the CSA A 23.2-25A Method