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Publisher's version / Version de l'éditeur:

Materials and Structures, 16, 94, pp. 243-250, 1983

National Research Council Canada
Conseil national de recherches Canada

RE–EVALUATION OF STANDARD MORTAR BAR AND CONCRETE PRISM TESTS FOR ALKALI–AGGREGATE REACTIVITY

by P.E. Grattan-Bellew

Reprinted from
Matériaux et Constructions
Vol. 16, No. 94, 1983
p. 243 - 250

DBR Paper No. 1140
Division of Building Research

Price $1.00 OTTAWA NRCC 22703

Canada

RÉSUMÉ

On examine l'efficacité de l'essai ASTM C227 sur des éprouvettes cylindriques de mortier et de l'essai ACNOR A23.2-14A sur des éprouvettes prismatiques de béton en vue de déterminer la réactivité aux alcalis de granulats classiques alcali-silice, de granulats siliceux à expansion tardive et de granulats alcali-carbonate. On souligne l'importance d'effectuer un examen pétrographique avant d'entreprendre l'évaluation de la réactivité aux alcalis de tous les types de granulats. On examine les limites d'expansion établies par l'ASTM, l'ACNOR, le U.S. Corps of Engineers et le U.S. Bureau of Reclamation ainsi que l'auteur, pour différencier les combinaisons béton-granulats dangereusement expansibles et celles qui ne présentent aucun danger, en vue de déterminer dans quelle mesure elles peuvent s'appliquer aux granulats classiques alcali-silice, aux granulats siliceux à expansion tardive et aux granulats alcali-carbonate réactifs.

Re-evaluation of standard mortar bar and concrete prism tests for alkali-aggregate reactivity

P. E. Grattan-Bellew

National Research Council Canada, Division of Building Research.

The effectiveness of the mortar bar ASTM C227 and concrete prism CSA A23.2-14A tests for evaluating the potential alkali-aggregate reactivity of classical alkali-silica, late expansive siliceous and alkali-carbonate aggregates is discussed. It is emphasized that petrographic examination is an essential preliminary step in the evaluation of potential alkali reactivity of all aggregates. The expansion limits set to differentiate between deleteriously expansive and innocuous cement-aggregate combinations by ASTM, CSA, U.S. Corps of Engineers, U.S. Bureau of Reclamation and by the author are evaluated for use with classical alkali-silica, late-expanding siliceous and alkali-carbonate reactive aggregates.

INTRODUCTION

The increased incidence of alkali-aggregate reactivity during the past decade has underscored the need for improved test methods and standards for the evaluation of potential alkali-aggregate reactivity of concrete aggregates. It has recently been shown that the use of "low alkali cement" ($\leqq 0.6\%$ Na_2O equivalent) has not, in some instances, been successful in preventing expansion and cracking of concrete made with reactive aggregate [1]. The petrographic method, CSA A23.2-15A [2], and the chemical method, ASTM C289 [3], could be combined to provide a good indication of the potential reactivity of aggregates, but such development will take time. Apart from this, there is little prospect for the development of new, rapid test methods in the next few years. There is, however, scope for improving present methods of evaluating the results of the mortar bar test ASTM C227 [4] and concrete prism test CSA A23.2-14A [5]. The rock cylinder method, ASTM C586 [6], is usually not satisfactory, although it may be appropriate in some instances. The petrographic method [2] will not usually yield an unambiguous result, although it forms a necessary part of any test since it is essential to determine whether alkali-silica, late-expansive alkali-siliceous or alkali-carbonate reactivity is to be expected before the results of either the mortar bar or concrete prism tests are interpreted.

The problem of establishing safe limits of expansion is complicated by the variation in the rates of expansion and the time taken for the main expansive phase of the reaction to commence. Variations in exposure conditions and the possible addition of alkalies to concrete through the use of de-icing salts on highways may have a marked effect on expansion of concrete due to alkali-aggregate reactivity and further complicate the problem of setting firm expansion limits. The establishment of satisfactory limits is, however, essential if test laboratories are to be able to evaluate the potential alkali-aggregate reactivity of samples with any confidence. The limits set forth in the current CSA and ASTM standards are satisfactory for some aggregates but quite unsatisfactory for others [7], and could lead to incorrect evaluation of the potential reactivity of an aggregate. One of the purposes of the present study was to evaluate the expansion limits proposed by various authorities and test their applicability to classical alkali-silica, late-expansive alkali-siliceous and alkali-carbonate reactive aggregates.

COMPARISON OF FIELD AND LABORATORY EXPANSIONS

A laboratory method of evaluating length change of concrete is only useful if it predicts with acceptable accuracy the expansion and cracking of concrete structures in the field. Measurements, however, have

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been made on very few concrete structures or large-scale test samples under Canadian exposure conditions, so that correlation between laboratory test results and deterioration of similar concrete in structures is uncertain. The relation between the expansion and cracking of concrete in the laboratory and that in the field is affected by a number of factors. In the laboratory, storage of samples at constant temperature and humidity enhances the reaction between the aggregates and the alkalies. In the field, concrete is subject to cycles of desiccation and low temperature, both of which slow the rate of reaction; as a result, laboratory samples expand faster than concrete structures in the field. In the long term, however, the additional stresses applied to concrete in the field by cycles of wetting and drying, which are known to cause deterioration by themselves [8], may result in greater damage than that observed in laboratory samples.

Expansion of concrete is related to its alkali concentration, which depends on the soluble alkali content of the cement, the cement content of the concrete, and the water/cement ratio. Increasing the watercement ratio dilutes the alkalies in the pore solution. It is important, therefore, to make test samples with the mix design that will be used in the field, or one in which the alkali content of the concrete will be at least as high as that planned for use in the structure. In the fabrication of concrete test prisms, CSA A23.2-14A [5] specifies a slump of 80 mm, which is achieved using a dry mix. The slump test is not normally carried out in the DBR/NRCC laboratory because it takes more aggregate than that required for the direct fabrication of a pair of concrete prisms. Reactive aggregate is usually only available in small quantities that have to be conserved for other tests. The test concrete is, instead, made with a w/c ratio of about 0.45, the minimum for a workable mix. In a trial using Ottawa limestone aggregate and a w/c ratio of 0.45, zero slump was observed. The use of a dry mix results in a higher concentration of alkalies in the pore solution of the concrete, giving rise to a more rapid expansion than would occur in field concretes made with higher w/c ratios.

The strength of the concrete and the presence of reinforcing steel may also have an effect on the expansion of concrete in the field. At present not much is known about this, except that reinforced concrete columns made with expansive cement-aggregate combinations generally develop longitudinal cracks [9]. Ideally, all factors should be taken into account in evaluating the results of laboratory tests.

The cracking of the concrete due to alkali-aggregate reactivity is one factor not considered by the current test methods, yet in most cases it is the cracking of the concrete and not the increase in length that causes the loss in strength of the structure. Possibly the development of microcracks should be taken as a sign of deleterious expansion in test specimens. The formation of microcracks can be readily observed with a low power stereo-microscope.

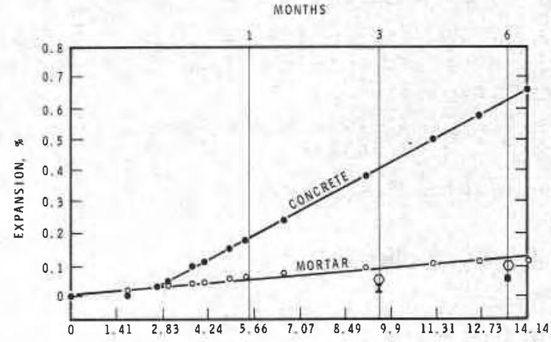

Fig. 1. — Comparison of expansions of concrete prisms and mortar bars made with #78-16 reactive carbonate aggregate from Kingston and high alkali cement. Limits given by various organizations are indicated: ASTM [17] ⬡, CSA [18] I, Corps of Engineers [13] ■.

MORTAR BAR AND CONCRETE PRISM TESTS

Both the mortar bar test (ASTM C227 [4]) and the concrete prism test (CSA A23.2-14A [5]) are effective for evaluating potentially expansive aggregates, although the mortar bar method usually gives much lower values of expansion than does the concrete prism test with alkali-carbonate expansive aggregates [10] (*fig.* 1). A summary of the limits of safe expansion according to various organizations is shown in table I. All the limits except CSA CAN3-A23.1-M77, Appendix B3.5 [11], apply to the mortar bar test. Experience in the DBR/NRCC laboratory indicates that mortar bars made with late-expansive siliceous aggregates generally show somewhat less expansion than do concrete prisms made with the same aggregate and cement. Figure 2 shows the expansion of concrete and mortar made with high alkali cement and a quartz arenite aggregate.

Typical expansion curves of concrete prisms or mortar bars made with three types of aggregate encountered in Canada are shown in figure 3. The classical alkali-silica reactive aggregate shown in figure 3 (sample I) is the mortar bar expansion (ASTM C227 [4]) of a sample of gravel containing an opal-bearing shale

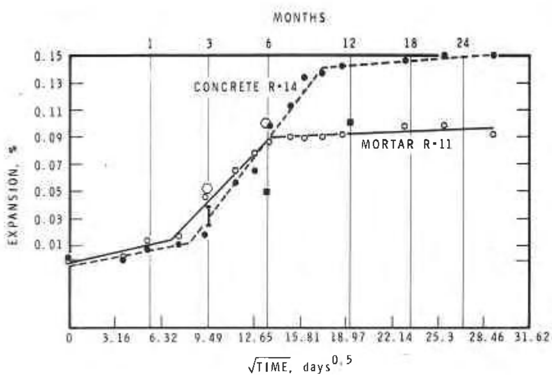

Fig. 2. — Comparison of expansions of concrete prisms and mortar bars made with a late-expansive siliceous aggregate, #74-55, a quartz arenite from Sudbury and high alkali cement. Limits given by various organisations are also indicated: ASTM ⬡, CSA I, Corps of Engineers ■. The rates of expansion are also indicated, $R = 14$.

from Saskatchewan. The late-expansive sample is the expansion curve of a concrete prism (CSA A23.2-14A [5]) of a greywacke from the Sudbury area of Ontario. The two curves of the expansion of concrete prisms (CSA A23.2-14A) shown as examples of alkali-carbonate reactivity are for samples from the Pittsburg quarry near Kingston, Ontario.

Classical alkali-silica reactivity

Sample I in figure 3, the results of the expansion of mortar bars made with a classical alkali-silica reactive aggregate, would be rated as deleteriously expansive by all evaluation methods. The limit of 0.20% specified by the U.S. Bureau of Reclamation [12] at 1 year is probably too high since many deleteriously expansive mortar bars will crack and cease to expand before this limit is reached; thus, samples that show deleterious expansion would be incorrectly classified as marginal or non-reactive. The U.S. Corps of Engineers specification, EM 1110-2-2000 [13], of 0.10% expansion at one year may be the optimum limit.

The rate method [14] correctly identifies sample I, (*fig.* 3) as deleteriously expansive, since the rate of 31 is well over the value of 7 tentatively suggested as the minimum value indicative of potentially expansive aggregate. It should be noted that all the rates listed are multiplied by 10^3 to simplify the values. Thus, a rate of 0.007 is simplified to 7. Too few examples of Canadian classical alkali-silica reactive aggregate are available for a relation between rate of expansion and ultimate expansion to be established. A plot of rate expansion versus percent expansion was made from a large number of mortar bar test results found in the literature and an equation relating the rate R to the ultimate expansion, E, was derived.

$$R = 18.284\,3 + 37.362\,3\,E. \qquad (1)$$

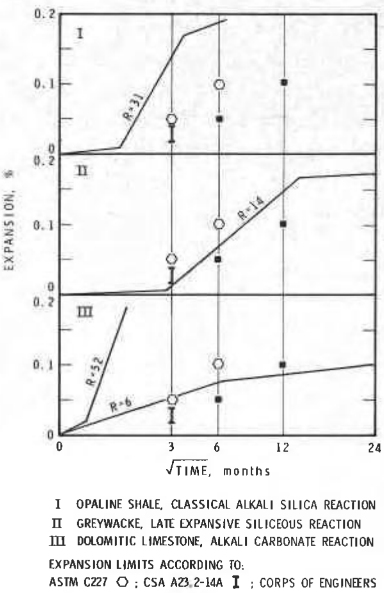

Fig. 3. – Diagram showing expansion characteristics of concrete prisms or mortar bars made with high alkali cement and three types of Canadian aggragate.

The confidence limit was only 0.724 1, indicating a lot of scatter of the points about the fitted regression line. This equation probably applies only to values of R between 20 and 100 and is therefore of limited use.

The concrete prism test is not usually used for evaluating classical alkali-silica reactive aggregates because it has been found that these aggregates cause greater expansion when ground to fine sizes [15]. The concrete prism test may, however, give a better idea of how much expansion can be expected in a concrete structure made with this type of aggregate.

Pessimum effect

The pessimum effect results in the maximum

TABLE I

Test Method	Limits Set (%)	Time (months)
Mortar Bar Test (ASTM C227 [4]):		
ASTM C33, App. XI.1.3 [17].	0.05	3
	0.10	6
	"demarcation between non-reactive and reactive combinations not clearly defined"	
CAN3 A23.1-M77, App. B3.4 [18].	0.04	any age
	"limits must be developed for each type of reaction"	
Corps of Engineers [13] EM 1110-2-2000 (Mortar bar test).	0.05	6
	0.10	12
	"slope and trend of expansion to be taken into consideration"	
Bureau of Reclamation [12] (Mortar bar test).	≧0.20	12
	marginal 0.10%-0.20	12
Rate Method (Mortar bar test).	≧7 (provisional)	any age
Concrete Prism Test, (CSA A23.2-14A [5]):		
CSA CAN3 A23.1-M77, App. B3.5 [11].	≧0.03%	any age
	0.02% moist conditions	3
	0.04% dry conditions	3
	"limits to be developed for each type of reaction"	
Rate Method (Concrete prism test).	≧7 alkali silica and late expansive siliceous aggregates	any age
	≧4 (tentative) for carbonate aggregates	any age

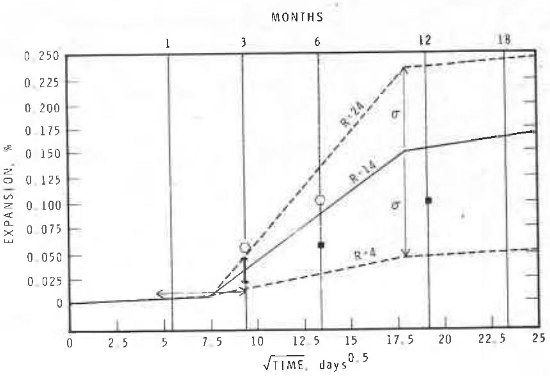

Fig. 4. — Graph showing the mean expansion of 20 concrete prisms made with high alkali cement and late-expansive siliceous aggregates from Canada. The mean rate of expansion is $R = 14$. Expansions with rates of 24 and 4, corresponding to the ± 1 standard deviation from the mean, are also shown. The ± 1 standard deviation from the mean time for the start of expansion is shown by: ↔ in expansion limits specified by: ASTM ⬡, CSA I, Corps of Engineers ■.

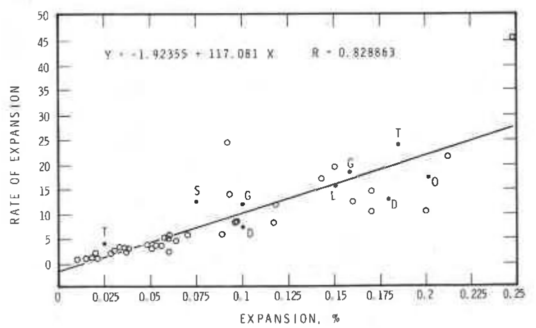

Fig. 5. — Rate of expansion versus per cent expansion of concrete prisms used in the preparation of figure 4. Expansions, per cent and rate for mortar bars or concrete prisms from various authors are also shown: S, Sims [22], G, Gillott [23], T, Gogte [24], D, Duncan *et al.* [25], O, Oberholster, Brandt and Weston [26], and L, Ottawa Limestone (see also *fig.* 8).

expansion of mortar or concrete made with reactive silica aggregate occurring when small amounts, commonly 5 to 20%, are present. Larger or smaller amounts decrease expansion. This effect is observed with aggregates containing opal, chert or other reactive silica minerals and with some volcanic glass. If only a small percentage of reactive silica is present, it reacts with the alkali completely during the first few days when the mortar is still relatively soft and expansion is minimal. When about 5 to 20% of reactive silica is present [16], the reaction continues after the mortar has stiffened and the gel produced then causes cracking. When larger amounts of the reactive silica occur in the aggregate the available alkali is rapidly neutralized so that by the time the paste is stiff, after 3 to 4 days, the reaction is over and again expansion is minimal. The pessimum effect must be taken into account when planning experiments to evaluate the potential alkali-aggregate of rock containing reactive silica. Because only a very small percentage of the aggregate is reactive in late-expansive siliceous aggregates, the pessimum occurs at 100%. Aggregates showing alkali-carbonate reactivity also show a pessimum at 100%.

Recently, classical alkali-silica reaction has been reported in lower Ordovician limestone from Montreal and Three Rivers, Quebec (personal communication, Jean Bérard, Ecole Polytechnique, Montreal). These aggregates appear to exhibit early expansion, but more research will be needed to define the expansion signature of mortar bars made with them.

Late-expansive siliceous aggregates

Either the concrete prism or the mortar bar method may be used to evaluate the potential reactivity of this type of aggregate, but the concrete prism test is preferred. In the author's experience it usually gives the most realistic expansion values because it utilizes the same aggregate size range as is found in field concrete. It also yields the most expansion. The test results of the expansion of concrete containing a greywacke (*fig.* 3, sample II) show less expansion than the limit set forth in CSA CAN3 A23.1-M77, App. B3.5 [11], and hence would be classed as innocuous. Mortar bar test results (ASTM C227 [4]) for this sample would show somewhat less expansion than the concrete prisms and would be classed as non-reactive according to ASTM C33 [17] limits. Interpretation, according to CSA CAN3-A23.1-M77, App. B3.4 [18], would class the sample as reactive since expansion is greater than 0.04%. This limit may, however, be too low; it is quite possible for a sample to show 0.045% expansion after the curve of expansion has levelled off and yet show no sign of cracking. A limit in the range of 0.07 to 0.10% might be more appropriate. The mortar bars would be classed as expansive according to the U.S. Corps of Engineers specifications [13]. A rate of expansion of 14 for the concrete prism would class this sample as deleterious according to the author's proposed limit of 7.

The mean expansion of 20 sets of concrete prisms made with high alkali cement (Na_2O equivalent 1.0%) and reactive aggregates from Northern Ontario, Quebec and Nova Scotia is shown in figure 4. The mean elapsed time before the onset of the main expansive phase is two months, with a standard deviation of ± 1 month. It is evident that at least for some samples the CSA limits of 0.02 to 0.04% at three months would be unsatisfactory since expansion would scarcely have commenced. Mortar bars having a similar expansion curve would be classed as non-expansive according to ASTM C33 [17]. The mean rate of expansion is 14 and corresponds to an ultimate expansion of 0.165% in one and a half years.

Lines with rates of 24 and 4, corresponding to one standard deviation on either side of the mean rate of expansion, are shown in figure 4. For assessment purposes the rate of 4 is probably too low and should be increased to 7; samples with a rate of 4 do not usually show any sign of cracking or deterioration. The upper value of 24 is known to cause deleterious expansion of concrete structures, e. g., Malay Falls, Nova Scotia [19]. The concrete prism with a rate of expansion of 14 showed considerable cracking after

12 months and is accordingly rated as deleteriously expansive. Test samples in the laboratory usually show a levelling off in expansion after one or 2 years, but it is unlikely that this would happen in actual concrete structures since they sometimes continue to expand after 20 years [20].

Although rates of expansion in excess of 7 are considered potentially deleterious in that they lead to cracking of test beams, it must be pointed out that concrete prisms made from aggregates known to have caused distress in concrete structures generally show much greater expansion, e. g., 45 for the argillite from Lady Evelyn Lake [21] and 24 for the greywacke from Malay Falls, Nova Scotia [19].

If rates of expansion give a good indication of the expansivity of the samples, then they should correlate well with the ultimate value when expansion has levelled off after 2 or 3 years. The relation between rate of expansion and ultimate expansion of the samples used in the preparation of figure 4 is shown in figure 5. Rate of expansion R is related to the ultimate percentage expansion E by:

$$R = -1.923\,55 + 117.081\,E \qquad (2)$$

There is, as might be expected, considerable spread on either side of the regression line. The correlation coefficient of 0.831 6, however, indicates a moderately good fit of the line to the points. Some additional mortar bar and concrete prism test results ([22]-[26]) are plotted on figure 5. These samples come from Cyprus, Alert, NWT, India, Nova Scotia, Cape Town, South Africa, and Ottawa, respectively. Points representing the samples fall well within the scatter points in figure 5, indicating that equation (2) may be applicable to mortar and concrete samples from many areas. It must be emphasized, however, that equation (2) applies strictly to concrete prisms made with late-expanding siliceous aggregates and high alkali cement. At present there is insufficient information available to estimate to what extent this equation would hold for different types of siliceous aggregate from other areas.

The major advantage of the rate method over other methods of evaluating the potential expansivity of aggregates by either the mortar bar or concrete prism test is that once the main expansive phase of the reaction has commenced an estimate of the expansivity of the sample may be obtained in 2 or 3 months. This is done by taking frequent readings (weekly) of length change. The rate may be established from five or six readings and an estimate of the expansivity calculated using equation (2). This will be illustrated with expansion data from a quartz arenite (quartzite) from the Sudbury area #74-46 [14]. Figure 6 *a* shows the 90-day expansion of the concrete test sample. With only the 3-month data, this sample would be rated as non-expansive. If a petrographic examination had been made, the sample would be identified as possibly of the late-expansive type and the investigator should, accordingly, continue the test for at least another two months before drawing any conclusion as to the potential reactivity of the sample. Figure 6 *b* shows the 6-month expansion data. CSA CAN3 A23.1-M77, App. B3.5 [11], specifies samples as expansive if expansion is greater than 0.03% at any age. This sample would therefore be rated as expansive, although no idea of the expansivity of the sample could be deduced and, as pointed out previously, the value of 0.03% may be too low because some non-expansive samples would be classed as deleteriously expansive if this limit were used.

Cracking in concrete prisms is usually observed when expansion exceeds about 0.04-0.05%, and it is thought that this might be a more realistic limit. If ASTM C33 [17] specifications were applied, it would be concluded that the sample was non-expansive. It would be rated as marginally expansive by the U.S. Corps of Engineers specifications [13] if these were also applicable to concrete prisms. From the seven readings on length change made between 3 and 6 months, a rate of expansion of 9 was determined. From this a calculated expansion of 0.093% was determined from equation (2). The measured expansion of this sample at 3 years was 0.16% and the rate determined after 2 years was 12. It may thus be concluded that although the rate and expansivity determined were low, the rate of expansion nonetheless gave a better indication of the expansivity of the sample than could be determined by other methods after 6 months of testing.

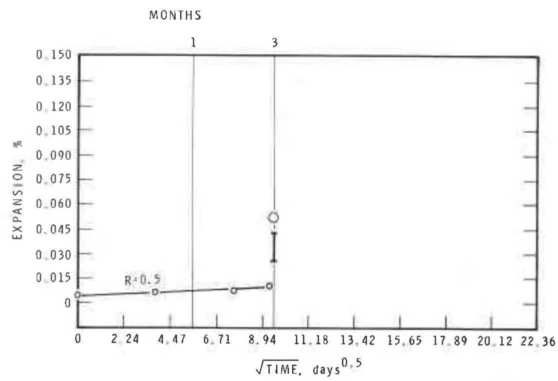

Fig. 6 *a*. — Graph showing 3-month expansion of concrete prism made with high alkali cement and quartz arenite aggregate from Sudbury, #74-46 [21]. The 3-month expansion limits, according to ASTM ◯, and CSA I, are also shown.

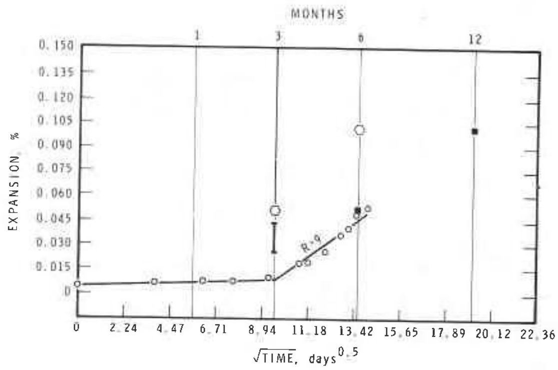

Fig. 6 *b*. — Expansion data of same samples at 6 months, showing change in rate after 3 months.

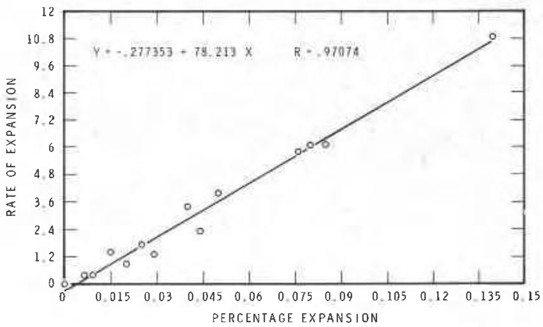

Fig. 7. — Graph of expansion, per cent versus rate for concrete prisms made with high alkali cement and alkali-carbonate expansive aggregates, after Hadley [27] and Grattan-Bellew [14].

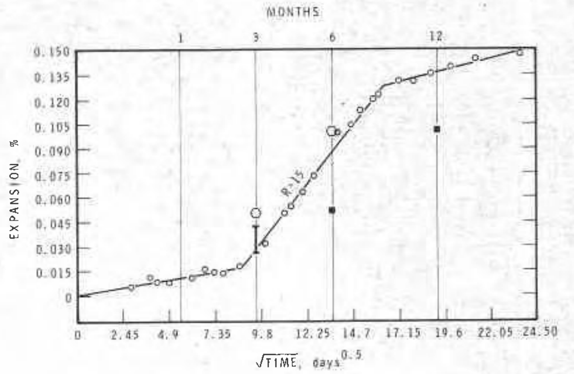

Fig. 8. — Expansion of concrete prism made with an Ottawa limestone and high alkali-cement that has an expansion signature characteristic of late-expansive siliceous aggregates. Expansion limits according to: ASTM ◯, CSA I, and Corps of Engineers ■, are also shown.

Alkali carbonate reactivity

The CSA specifications, CAN3 A23.1-M77, App. B3.5 [11], are satisfactory for concrete prisms made with alkali-carbonate expansive aggregates, but estimation of ultimate expansion is not possible from values recorded during the first few months. The Corps of Engineers specifications would also be satisfactory, assuming that they were applicable to concrete prisms. Because the main expansive phase of the reaction commences within weeks of the start of the experiment, the rate of expansion can be established within one or 2 months. Owing to insufficient concrete prism results from Canadian aggregates, data from Hadley [27] were combined with those of the author in a plot of rate versus percentage expansion when the slope of the expansion curve had levelled off (*fig.* 7). The correlation coefficient of 0.990 74 indicates a very good fit of the regression line to the points on the graph. The rate of reaction R is related to the ultimate expansion E by the following equation:

$$R = -0.277\,353 + 78.213\,E. \qquad (3)$$

It would seem that this equation can be used with considerable confidence to predict the expansivity of alkali-carbonate expansive aggregates. Care must be exercised, however, to make sure that expansion is due to alkali-carbonate reactivity. Figure 8 shows the expansion of concrete prisms containing a carbonate aggregate from Ottawa and high alkali cement (Na_2O equivalent 1.08%). Almost no expansion occurred in the first three months and this could easily lead an investigator to conclude that the sample was non-expansive, on the assumption that it was a carbonate-expansive type of aggregate. The shape of the expansion curve is typical of late-expansive siliceous aggregates and other evidence confirms this diagnosis. The concrete prisms have a rate of expansion of 15; they had expanded 0.15% in under 2 years and had cracked.

The rate of expansion of 7 used to differentiate satisfactory and deleteriously expansive cement-aggregate combinations of late-expansive siliceous aggregates is probably too high for use with potentially expansive carbonate aggregates, owing to the rapid initiation of expansion and the maintenance of the initial rate for a long period with this type of aggregate. For example, a sample with a rate of 5.8 expanded by just under 0.1% in 3 years and showed much cracking, indicative of a deleteriously expansive reaction. A second sample, with a rate of 2.3, expanded by 0.05% in 3 years and showed only minor cracking, suggesting, at worst, marginal expansivity. Possibly a value of 4 would be optimum for distinguishing between safe and deleteriously expansive concrete prisms.

Some carbonate aggregates from the Gull River formation in southwestern Ontario were classified as late-expansive [28] by the rock cylinder method, ASTM C586 [6]. As no published data on the expansion of concrete prisms made with this aggregate exist, it is not known whether concrete would also exhibit late expansion; if so, care would be needed in the interpretation of test results. It is probable that if all concrete prisms were measured for a minimum of 6 months, any late-expansive samples would be identified and their potential expansivity correctly determined.

CONCLUSION

Three types of alkali-aggregate reactivity are found in Canada: classical alkali-silica; late-expansive siliceous; alkali-carbonate reactive. Each has its own characteristic time-expansion signature, the result of the variation in the interval before the start of the main expansive phase of the reaction and the length of time for which it is maintained. It is therefore essential to carry out some form of petrographic examination, e. g., CSA A23.2-15A [2], to determine the probable type of reactivity to be found before interpreting mortar bar or concrete prism test results.

The mortar bar method (ASTM C227 [4]) gives the most rapid results with classical alkali-silica reactive aggregates, but it is unsuited for use with alkali-carbonate reactive aggregates. The concrete prism test is the only satisfactory method of evaluating potentially expansive alkali-carbonate aggregates, although in quarries containing reactive aggregate the rock prism method [6] may be used to advantage to delineate the expansive horizons. In the author's view the concrete prism test is also the preferred method for use with late-expansive siliceous aggregates.

The limits of safe expansion set by various organizations are not entirely satisfactory. Those set out in ASTM C33, App. XI.1.3 [17], for the interpretation of the results of mortar bar expansions, i. e., 0.05% at 3 months or 0.10% at 6 months, are satisfactory for classical alkali-silica reactive aggregates but not for the late-expansive siliceous variety. The specification of expansions in excess of 0.04% at any age in CSA CAN A23.1-M77, App. 3.4 [18], is probably too low; a value in the range of 0.05 to 0.10% may be more realistic. The U.S. Corps of Engineers specification of 0.10% at 1 year [13] is generally satisfactory, but the U.S. Bureau of Reclamation value of 0.20% [12] is probably too high for use with Canadian aggregates.

The minimum expansion indicative of deleterious expansion of concrete prisms, according to CAN3 A23.1-M77, App. B3.5 [11], is 0.03% at any age. This value may be satisfactory for carbonate aggregates but is too low and should be revised in the range of 0.05 to 0.10% for other types of aggregate. The other specifications discussed in this paper were not designed for use with concrete prisms. Nevertheless, the Corps of Engineers specifications of 0.05% at 6 months and, more particularly, 0.10% at 1 year would be satisfactory.

The rate method of interpretation gives satisfactory results with all types of aggregate for both mortar bar and concrete prism tests. It has the advantage that the rate can be determined within a few months of the start of the main expansive phase of the reaction and that an estimate of the expansivity of the test samples can be obtained for classical alkali-silica, late-expansive siliceous and alkali-carbonate reactive aggregates from equations (1), (2) and (3), respectively.

Finally, it must be stressed that exposure conditions must be taken into account in interpreting results of tests for alkali-aggregate reactivity, regardless of the limits used. Drawing water through retaining walls by evaporation from the exposed surface or addition of de-icing salts may concentrate alkalies locally and cause excessive expansion in concrete that would otherwise be considered, at worst, marginally expansive.

ACKNOWLEDGEMENTS

The author is indebted to P. J. Lefebvre for the preparation and measurement of many mortar bar and concrete prisms and for plotting the graphs of the results of the experiments used in the preparation of this publication. He also wishes to acknowledge useful discussions with colleagues on the CSA Subcommittee on Alkali-Aggregate Reactivity. This paper is a contribution from the Division of Building Research, National Research Council Canada, and is published with the approval of the Director of the Division.

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RÉSUMÉ

Réévaluation des éprouvettes d'essai normalisées de mortier et de béton pour l'étude de la réactivité alcali-granulat. – *Pour la détermination de la réactivité potentielle des granulats du béton, il est indispensable d'établir des limites sûres de variations dimensionnelles pour les éprouvettes d'essai de mortier et de béton. La définition de ces limites se trouve compliquée par la variation de vitesse d'expansion des différents types de granulats. Ainsi, la limite ASTM de 0,05 % à 3 mois pour l'expansion des éprouvettes de mortier peut être satisfaisante dans le cas classique alcali-granulat siliceux (par ex. opale, silex et verre volcanique) mais non pas pour les granulats siliceux après 3 mois à expansion tardive (par ex. quelques quartzites, argillites et grès schisteux). L'application mal appropriée de limites peut conduire à une estimation incorrecte de l'expansivité potentielle d'un granulat.*

L'expansion du béton confectionné avec des granulats réactifs se relie directement à l'alcalinité des solutions interstitielles, qui est déterminée par la teneur en alcali soluble dans l'eau du ciment. La teneur en ciment du béton est le rapport eau/ciment. Il est donc important que la solution interstitielle des éprouvettes renferme une teneur en alcali au moins aussi élevée que celle qui se présentera dans le béton mis en œuvre. Lorsqu'on procède à l'essai d'un type classique de granulat sur éprouvette de mortier à réaction alcali-silice, les limites de 0,05 % à 3 mois ou de 0,10 % à 6 mois spécifiées dans ASTM C33-78, Annexe 11, sont généralement satisfaisantes comme les limites de 0,05 à 6 mois ou de 0,10 à 12 mois spécifiées par le US Corps of Engineers. La méthode décrite par l'auteur donne également des résultats satisfaisants bien qu'il faudrait un complément de recherche pour arrêter des limites définies. Cet essai sur éprouvette de mortier se confirme comme n'étant pas effectif pour les granulats à réaction alcali-carbonate et pour quelques grès siliceux à expansion tardive. L'essai sur prisme de béton est préférable pour ces types de granulat mais les limites de 0,02 à 0,04 % à 3 mois prescrites par le Canadian Standard Association ne sont pas satisfaisantes dans le cas de granulats à expansion tardive.