

Bristol Channel it is important to develop test methods which will reliably predict the alkali reactivity of such aggregates. The results so far of the assessment of possible test methods indicate that ASTM test methods, especially the C227 mortar bar test, can give misleading answers for UK materials but that tests using concrete specimens are more helpful. Tests using such concrete specimens have shown definite pessimum effects for some aggregates. The lack of expansion in mortar bars when concrete prisms containing the same amount of alkali and made with the same water/cement ratio and aggregate/ cement ratio crack and expand markedly is puzzling.

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STANDARD ALKALI-REACTIVITY TESTING OF CARBONATE ROCKS FROM THE MIDDLE EAST AND NORTH AFRICA

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1. ABSTRACT

This paper arises from the experience of applying the standard rock cylinder test (ASTM C586-69) to variably argillaceous dolomites, limestones and dolomitic limestones from the Middle East and North Africa. Three case studies are presented, one involving an impure dolomite which exhibited delayed expansion in the rock cylinder test, and two similar rocks involving an impure limestone and a dolomitic limestone, from adjacent parts of one quarry, which exhibited unusually large and progressive contraction.

Comparisons are made between the rock cylinder test results and the petrological compositions and textures of the rock samples. The applicability of the rock cylinder test method for Middle Eastern and North African carbonate rocks is critically considered and an attempt is made to provide guidelines for the correct interpretation of rock cylinder test results for these materials.

Key Words: Carbonate, Alkali-Reactivity, Testing, Aggregate.

2. INTRODUCTION

Alkali-carbonate reactivity in concrete is very much less common than alkali-silica reaction. Nevertheless it remains a potential threat to concretes made using carbonate aggregates without a record of previous usage.

Since its discovery by Swenson in 1957 /1/ several distinct types of alkali-carbonate reaction have been identified /2/3/4/. These different types of reaction have been related to specific combinations of compositional and petrographic features of the rock involved and the effect of alkalies on the concrete and aggregate alike /5/6/.

Various tests for assessing potential alkali-carbonate reactivity have been used /7/8/9/10/11/. The ASTM C586-69 /12/ 'rock cylinder test' is similar to tests used by many research workers and involves the determination of the volume change of carbonate rocks when immersed in 1N NaOH solution at room temperature (say 20°C). The results from this test should not be considered as 'pass/fail' criteria for a rock proposed for use as concrete aggregate. However, they indicate whether further investigations should be carried out to determine the effect of aggregate prepared from the rock upon the dimensional change of a concrete.

The ASTM C586-69 test was originally described for North American carbonated rocks which sometimes exhibit significant expansion. For example, the argillaceous dolomitic limestone from Kingston, Ontario, has been found to produce rock cylinder expansions substantially in excess of 0.1% within two to three weeks /13/. The application of this test to dolomitic rocks from the Middle East and North Africa has shown that they frequently contract for a period of time, after which they sometimes start to expand /13/.

Lemish and Moore /9/ classified the carbonate rocks, with regard to their expansive tendencies in alkaline solutions, into four categories:

- Category I : Rocks which expand in excess of 0.5%
- Category II : Rocks which expand between nil and 0.5%
- Category III: Rocks which contract prior to expanding
- Category IV : Rocks which contract steadily

Also Dolari Mantuani /14/ described three groups:

- Minor-expansion group showing expansion from 0.1% to 0.39%.
- Early-major expansion group showing expansion of at least 0.40% in 2 to 5 weeks.
- Late-major-expansion group showing expansion of at least 0.40% starting after 25 weeks.

The late-major-expansion group of rocks is characterised by very finely crystalline dolomite aggregations containing dolomite rhombohedra and quartz enveloped by a very fine matrix of clay minerals and carbonate. The acid insoluble residue comprises between 25% and 30% and consists of almost equal amounts of quartz and clay minerals /14/.

3. TEST PROCEDURES

The three carbonate rocks were from Libya and they included an argillaceous dolomite (Sample 6) and two rocks taken from different faces of one quarry. One of these two rocks was an impure limestone (Sample 3D) whilst the other was a dolomitic limestone (Sample 2D).

The three rock samples were chemically analysed for CaO, MgO, and acid insoluble residue. The acid insoluble residue of each of the three rocks was further subjected to x-ray diffraction analysis in order to determine the mineralogical composition with particular reference to the types of any clay minerals present. The relative density and water absorption of the samples were determined in general accordance with BS.812:Part 2:1975 /15/. Thin sections were prepared and stained for the identification of carbonate minerals. The acid insoluble residues were mounted in immersion oil and examined under the petrological microscope. The results are given in Table 1.

TABLE 1. Characteristics of the Samples.

Sample Ref:	6	3D	2D
Average Grain Size, μm :	40	5	5
Relative Density:	2.80	2.67	2.65
Water Absorption, %:	2.30	0.80	1.89
CaO, % by wt:	26.93	50.90	46.33
Calcite, % by wt:*	0	89.00	76.60
MgO, % by wt:	19.83	0.75	3.66
Dolomite, % by wt:*	89.50	3.40	16.70
Acid Insoluble Residue, % by wt:	7.40	8.47	9.36
Apparent Nature and Constituents of the Insoluble Residue, %:#	Quartz: 10 Kaolinite) and)90 Muscovite)	Quartz: 40 Palygorskite) and)60 Chamosite)	Quartz: 40 Palygorskite) and)60 Chamosite)

* Calculated mineralogy, assuming all magnesia is present as dolomite.
Qualitative determination by x-ray diffraction of insoluble residues.
Proportions estimated by visual examination under the microscope.

The ASTM C586-69 rock cylinder test was carried out for each rock sample using one specimen drilled normal to the bedding and the other parallel to the bedding. All rock cylinders were prepared with flat ends. Length change measurements were carried out after periods of immersion in 1N NaOH solution at $20 \pm 2^\circ$ of 7 days, 14 days, 21 days, 1 month and thereafter at monthly intervals. In addition, the weight changes were also recorded.

After periods of immersion of up to 15 months, the rock cylinders from Samples 6 and 3D, which showed the highest expansion and contraction respectively, were used to prepare thin sections for comparison with the fresh rock. Chips from the same specimens were used for electron probe microanalysis. Area and spot analyses and microphotographs were also taken.

In order to check the reproducibility of the ASTM C586 test results, duplicate cylinders were drilled from Samples 3D and 2D and re-tested.

4. RESULTS

4.1. Petrographic Examination of the Samples

4.1.1. Sample 6

The rock was a light grey/greenish indurated intact-foliated dolomite exhibiting feint irregular bedding ranging in the millimetre to centimetre scale. The slight stratification was not reflected by the microstructure of the rock, which exhibited mosaic texture and consisted of anhedral and infrequently subhedral dolomite grains with a remarkable uniformity in grain size ranging from about $60\mu\text{m}$ to $10\mu\text{m}$ with a modal size of about $40\mu\text{m}$.

The dolomite grains were closely packed showing clear-cut straight boundaries rather than interlocking and they exhibited a murky appearance due to very fine inclusions. Frequently hydrated iron oxide appeared along the grain boundaries. Irregular quartz grains of $20\mu\text{m}$ to $50\mu\text{m}$ were sporadically present. Open voids of $30\mu\text{m}$ average size were infrequently observed.

The insoluble residue was found to consist of about 90% clay-like material and 10% silt size quartz.

4.1.2. Sample 3D

The rock was a pale red-brownish indurated intact-foliated limestone exhibiting somewhat irregular rippled wavy bedding structures. It was an intrabiomicrite /16/.

The intraclasts ranged from the millimetre to pelletal size exhibiting a dark brown appearance. They consisted of very finely crystalline calcite and relict bioclastic debris which have been replaced by micrite and occasionally by microspar. Infrequently intraclasts exhibited peripheral attrition rims. Assimilation of the intraclasts, probably due to diagenetic processes, by the micritic matrix was frequent.

The micritic matrix contained relict bioclastic debris similar to that in the intraclasts. The bioclasts have been replaced by micrite and/or microspar but sparry calcite replacements were occasionally observed. Microspar and occasionally sparry calcite replacements of the micritic matrix were infrequently present giving rise to grumose structure or more rarely filling voids and veins. Microcrystalline silica intermixed with calcitic mud very occasionally replaces parts of bioclasts or infilled voids. Infrequent subrounded to irregular quartz grains ranging in size from $5\mu\text{m}$ to $80\mu\text{m}$ were also present in the rock. Voids of $25\mu\text{m}$ average size were sometimes observed.

The acid insoluble residue was found to consist of approximately 60% clay-like material and 40% silt size quartz.

4.1.3. Sample 2D

The rock was a pale-brown indurated intact-foliated dolomitic limestone. It appears to exhibit macroscopical and microscopical similarities to Sample 3D but the following differences were observed:

- Frequent open vuggy voids ranging in size from about 10 μ m to 1mm and averaging approximately 200 μ m.
- Infrequently dolomite anhedral to subhedral crystals, ranging in size from 5 μ m to 80 μ m, appear to infill voids or cracks.
- Assimilation of intraclasts by the micritic matrix has proceeded further.

4.2. X-Ray Diffraction Analysis

The qualitative x-ray diffraction results for the acid insoluble residues are given in Table 1. The dolomite (6) was found to contain quartz, kaolinite and muscovite, whilst the limestone (3D) and the dolomitic limestone (2D) were both found to contain quartz, palygorskite and chamosite in minor amounts.

4.3. Potential Alkali-Reactivity Testing (ASTM C586-69)

The rock cylinder test results are detailed in Table 2, and the length change curves are included in Figure 1.

The cylinders taken from the dolomite (6) exhibited an initial contraction until the second month, after which they started to expand, and after four months the expansion exceeded 0.1%. The rate of expansion for the rock cylinder drilled normal to the bedding appeared to be greater than that drilled parallel. The expansion for both cylinders showed a constant increase until the ninth month, after which it ceased.

The rock cylinders from the limestone (3D) showed contraction which, for the cylinder drilled normal to the bedding, became -0.18% in the third month and continued to contract until the sixth month, after which it stabilised. The rock cylinder taken parallel to the bedding exhibited small scale contraction which was stabilised from the fifth month onwards.

The rock cylinders from the dolomitic limestone (2D) exhibited an incipient expansion which was followed by contraction in a similar pattern to that of the limestone (3D), but with a lower rate and magnitude. The cylinder taken normal to the bedding showed a maximum contraction of -0.13% after nine months.

The weight of the cylinders from Sample 6 showed an initial increase up to the second month, after which it started to decrease and continued doing so up to fifteen months with a maximum weight loss of about 2%. In Figure 2 the weight change is plotted against length change. The rock cylinder taken normal to the bedding showed a final expansion of 0.24% with a respective weight loss of 1.64%, while the cylinder taken parallel to the bedding exhibited a smaller final expansion of 0.15% with a maximum respective weight loss of 1.93%.

The weight of the cylinders taken from Sample 3D showed an initial increase up to the first month after which it decreased up to thirteen months with a maximum weight loss of 0.07%. Both rock cylinders exhibited similar rates of weight change.

TABLE 2. Potential Alkali-Reactivity Test Results.

Sample No	6				3D				2D			
	Normal		Parallel		Normal		Parallel		Normal		Parallel	
Reference Length (mm)	45.022		45.034		35.060		34.960		34.990		34.850	
Reference Weight (g)	14.3200		14.1963		5.3304		5.6575		5.4930		5.5950	
Period of Immersion in Alkaline Solution	L	W	L	W	L	W	L	W	L	W	L	W
7 Days	0	+0.06	0	+0.06	0	+0.10	0	+0.04	+0.029	+0.16	+0.014	+0.18
14 Days	-0.005	+0.06	0	+0.07	0	+0.11	0	+0.06	-0.036	+0.15	0	+0.17
21 Days	0	+0.07	-0.005	+0.09	-0.014	+0.11	0	+0.06	-0.036	+0.27	0	+0.25
1 Month	-0.005	+0.08	-0.005	+0.09	-0.014	+0.09	0	+0.09	-0.036	+0.38	0	+0.39
2 Months	0	+0.10	-0.005	+0.08	-0.083	+0.05	0	+0.09	-0.028	+0.29	0	+0.30
3 Months	+0.045	+0.05	+0.045	+0.06	-0.181	+0.07	-0.036	+0.03	-0.064	+0.33	-0.022	+0.35
4 Months	+0.184	-0.17	+0.116	-0.07	-0.202	+0.04	-0.020	+0.04	-0.110	+0.30	-0.040	+0.31
5 Months	+0.192	-0.31	+0.118	-0.27	-0.246	+0.03	-0.022	+0.01	-0.109	+0.35	-0.036	+0.36
6 Months	+0.203	-0.34	+0.118	-0.40	-0.217	0	-0.022	0	-0.102	+0.37	-0.029	+0.39
7 Months	+0.213	-0.45	+0.124	-0.53	-0.217	-0.03	-0.022	-0.01	-0.102	+0.39	-0.029	+0.43
8 Months	+0.220	-0.63	+0.124	-0.73	-0.217	-0.03	-0.022	-0.01	-0.109	+0.42	-0.022	+0.43
9 Months	+0.237	-1.14	+0.152	-1.40	-0.217	-0.05	-0.022	-0.07	-0.131	+0.42	-0.007	+0.44
10 Months	+0.232	-1.43	+0.141	-1.69	-0.217	-0.05	-0.022	-0.07	-0.109	+0.42	-0.022	+0.43
11 Months	+0.232	-1.47	+0.141	-1.77	-0.217	-0.07	-0.022	-0.01	-0.109	+0.43	-0.029	+0.43
12 Months	+0.232	-1.62	+0.141	-1.90	-0.217	-0.05	-0.015	-0.06	-0.102	+0.44	-0.015	+0.43
13 Months	-	-	-	-	-0.217	-0.05	-0.022	-0.07	-0.116	+0.45	-0.036	+0.44
15 Months	+0.236	-1.64	+0.146	-1.93	-	-	-	-	-	-	-	-

Notes: L: Rock cylinder length change percent.
W: Rock cylinder weight change percent.
+: Indicates increase in length or weight.
-: Indicates decrease in length or weight.

The weight of the cylinders from Sample 2D showed a constant weight gain up to thirteen months with a maximum weight increase of 0.45%. Both cylinders exhibited similar rates of weight change. The weight change results for Samples 3D and 2D do not correlate with the length change results obtained for these samples.

4.4. Petrographic Examination of the Samples Soaked in NaOH Solution

The rock cylinder from the dolomite (6) which exhibited the highest expansion after 15 months, and the cylinder from the Limestone (3D) which showed the largest contraction after 13 months, were examined in thin section under the petrological microscope.

4.4.1. Sample 6 (Soaked)

The grain boundaries between the dolomite crystals exhibited a distinct opening suggesting an enhanced grain boundary mobility. The intergranular spaces occasionally appeared to be up to 2µm in width. Rarely the intergranular spaces and voids were partially infilled with calcite. The rock exhibited a general 'scruffy' appearance with a loosening of the close packing of the dolomite grains which form the mosaic texture (Plate 1 a, b, c and d). Nevertheless, no zonation or apparent corrosion of the dolomite grain boundaries was observed.

3.4.2. Sample 3D (Soaked)

Due to the very finely crystalline nature of the rock no structural changes or any reaction products could be observed under the petrological microscope.

4.5. Electron Probe Microanalysis

Chips from the (6) and (3D) cylinders soaked in NaOH solution, and from the relevant fresh rock, were examined under an electron microscope. Four area analyses from each of the four specimens were taken and then averaged. The results are given in Table 3.

In dolomite (6) there was a small decrease in silica and alumina contents and an apparent increase in Na₂O content in the soaked specimen, whereas in the limestone (3D) no apparent compositional changes could be observed.

TABLE 3. Average Area Analyses of Fresh and Soaked Rocks.

Sample Ref:	6				3D			
	Fresh		Soaked		Fresh		Soaked	
Average Oxide Content	%	S	%	S	%	S	%	S
CaO	52.59	2.25	54.35	2.51	80.18	0.82	80.30	2.67
SiO ₂	11.34	0.50	8.10	0.22	12.41	0.03	12.09	1.20
Al ₂ O ₃	4.90	0.37	3.41	0.21	2.67	0.20	3.09	0.63
FeO*	1.94	0.42	2.10	0.03	1.30	0.16	1.70	0.16
Na ₂ O	0.75	1.06	1.60	0.78	0.32	0.45	0.45	0.64
K ₂ O	0.68	0.05	0.48	0.00	0.55	0.04	0.79	0.01
MgO	27.13	0.21	29.74	1.29	2.07	0.05	1.12	0.29
MnO	0.06	0.08	0.00	0.00	0.10	0.13	0.02	0.03
TiO ₂	0.48	0.32	0.14	0.01	0.09	0.09	0.23	0.05
Cl	0.03	0.03	0.06	0.05	0.06	0.03	0.15	0.10
SO ₃	0.11	0.12	0.02	0.03	0.29	0.14	0.13	0.17
Total	100.01	-	100.00	-	100.04	-	100.7	-

Note: *Total Iron as FeO. S = Standard deviation.

Comparative examination of the fresh and soaked dolomite (6) specimens revealed an overall 'scruffy' appearance of the soaked specimen (Plate 3 a and b) and, in high magnifications, a loosening of the close packing of the dolomite grains was also observed. Probing central and peripheral parts of grains in both fresh and soaked specimens showed that some grains in the soaked specimen exhibited a calcitic centre and peripheral parts with a high magnesium concentration (Plate 4). This may suggest that magnesium ions have migrated towards the periphery of the grain, where the main chemical activity is taking place, depleting the centre of magnesium.

Kaolinite grains were infrequently observed in the fresh Sample 6 (Plate 2) while in the soaked specimen kaolinite grains were not observed.

The limestone (3D) specimens, although they did not show any obvious change by the area analysis, did exhibit textural and mineralogical differences under the electron microscope. The granular texture in the fresh specimen appears to have decreased in grain size in the soaked specimen, together with the formation of abundant calcium hydroxide plates (Plate 5 a and b).

4.6. Repeated Test for Potential Alkali-Reactivity (ASTM C586-69)

The limestone (3D) and the dolomitic limestone (2D) were subjected to a repeated rock cylinder test.

The length and weight changes of the cylinders from both samples exhibited very similar patterns to those of the first test. However the length change appeared to be of a much lower rate and magnitude with a maximum contraction of 0.04%. The weight changes also showed minor differences to the first test (Figure 1 b and e).

5. DISCUSSION

The three rocks exhibit a diversity in composition and they involve a dolomite (6), a limestone (3D) and a dolomitic limestone (2D). They each contain a small amount of acid insoluble residue which consists of quartz and non-swelling types of clay minerals. Structurally the rocks consist of grains ranging from finely crystalline (dolomite) to very finely crystalline and aphanocrytalline size (limestone and dolomitic limestone).

The dolomite exhibits a textural uniformity, whereas in the other two samples there is a textural variability. This textural variability, however, is very similar in both samples with the difference that the dolomitic limestone appears to be more porous. The water absorption values are low for all three rocks and they are mechanically hard and tough.

Both rock cylinders from dolomite (6) expanded excessively after four months and they also ceased expanding after nine months. The expansion appears to be the result of the opening of the close packing of the dolomite grains in the rock structure. The calcite infilling intergranular spaces, and also the grains exhibiting calcitic centres and dolomitic peripheries, suggest that dedolomitization has occurred in the soaked specimens.

Intragranular kaolinite is present in the dolomite grains of Sample 6 and they were observed in the fresh rock specimen, but not in the soaked specimen, possibly due to breakdown and partial leaching into the alkaline solution. The latter possibly accounts for the large reduction in the weight of the cylinders, and also the decrease in silica and alumina recorded by microanalysis.

The opening of the structure may be explained by the hypothesis suggested by Gillott /10/ according to which dedolomitization and previously "unwetted" or "active" clay minerals are thought to be responsible for the expansion of dolomitic rocks.

The recording of weight change is not recommended by the ASTM C586-69 standard test, neither is this a common practice in published research. Nevertheless, the recording of weight change frequently proves helpful in understanding the mechanisms involved in producing length changes in the rock cylinder test.

Both rock cylinders from dolomite (6) showed delayed weight loss, which coincided with the commencement of the expansion and also continued after the expansion had ceased. Thus, in Sample 6, the weight changes appear to correlate with the length changes, whereas for Samples 3D and 2D no correlation was apparent. The considerable weight loss for Sample 6 suggests that reaction products may be leached into the solution through the opened intergranular spaces. Also the opening of the structure and the leaching may impair the strength of the rock.

The limestone (3D) and the dolomitic limestone (2D) showed a steady contraction, which, for the cores taken normal to the bedding, exceeded -0.1% after 3 and 4 months respectively. The expansion level normally exceeded by deleterious rocks is suggested by ASTM C586-69 to be 0.1%, and no guidance is provided in the standard for contraction. Nevertheless concrete aggregates showing excessive contraction (or 'shrinkage' usually attributed to drying) are considered to be deleterious /17/.

The cylinders from Samples 3D and 2D, after 13 months immersion, showed an overall grain size reduction together with the formation of abundant plates of calcium hydroxide /3/. The cylinders from Sample 3D increased in weight initially and then slightly decreased, whereas those from Sample 2D increased constantly. Maximum contraction for both samples was attained when maximum weight change occurred.

The different trends in weight change are thought to be due to the differences in water absorption and the nature of the void system of the samples. Possibly reaction products of low solubility can be precipitated in the open vuggy voids of Sample 2D, whereas in Sample 3D, which is less porous, they could be leached into solution.

Various physical processes have been postulated as causes of contraction of rock cylinders kept continuously wet, including migration of water out of the surrounding solution /18/. Syneresis is another possibility. Dissolution of limestone by alkali and salt solutions has been followed on the scanning electron microscope and may also be a contributory factor /19/.

The lower values of contraction obtained by the repeat test are thought to reflect lithological variations. The similarity in the contraction pattern indicates that the rock contracts steadily, but at a different rate and magnitude in different parts of the rock mass.

6. SUMMARY

The ASTM C586-69 rock cylinder test method was used for the assessment of potential alkali-carbonate reactivity of three rock samples from Libya.

The three rocks involved a dolomite (6), a limestone (3D) and a dolomitic limestone (2D).

The dolomite (6) showed an initial contraction followed by an excessive delayed expansion, which corresponded with an initial weight gain followed by a progressive loss in weight.

The limestone (3D) and dolomitic limestone (2D) each exhibited a contraction which could not be correlated with the weight change.

Rock cylinders from Middle Eastern and North African carbonate rocks frequently show initial contraction when immersed in alkaline solution. No guidance regarding such behaviour is given in ASTM C586. This contraction should be monitored until a stable length change has been achieved, thus ensuring that delayed expansion is unlikely to take place.

Should delayed expansion take place, it should be similarly monitored until either a stable length change has been achieved or the +0.1% level has been exceeded, whichever is the sooner. These tentative recommendations inevitably will tend to increase the length of time required for the satisfactory completion of a test programme.

In addition to the measurement of length change, the recording of weight change is found to be useful in the interpretation of the rock cylinder test results.

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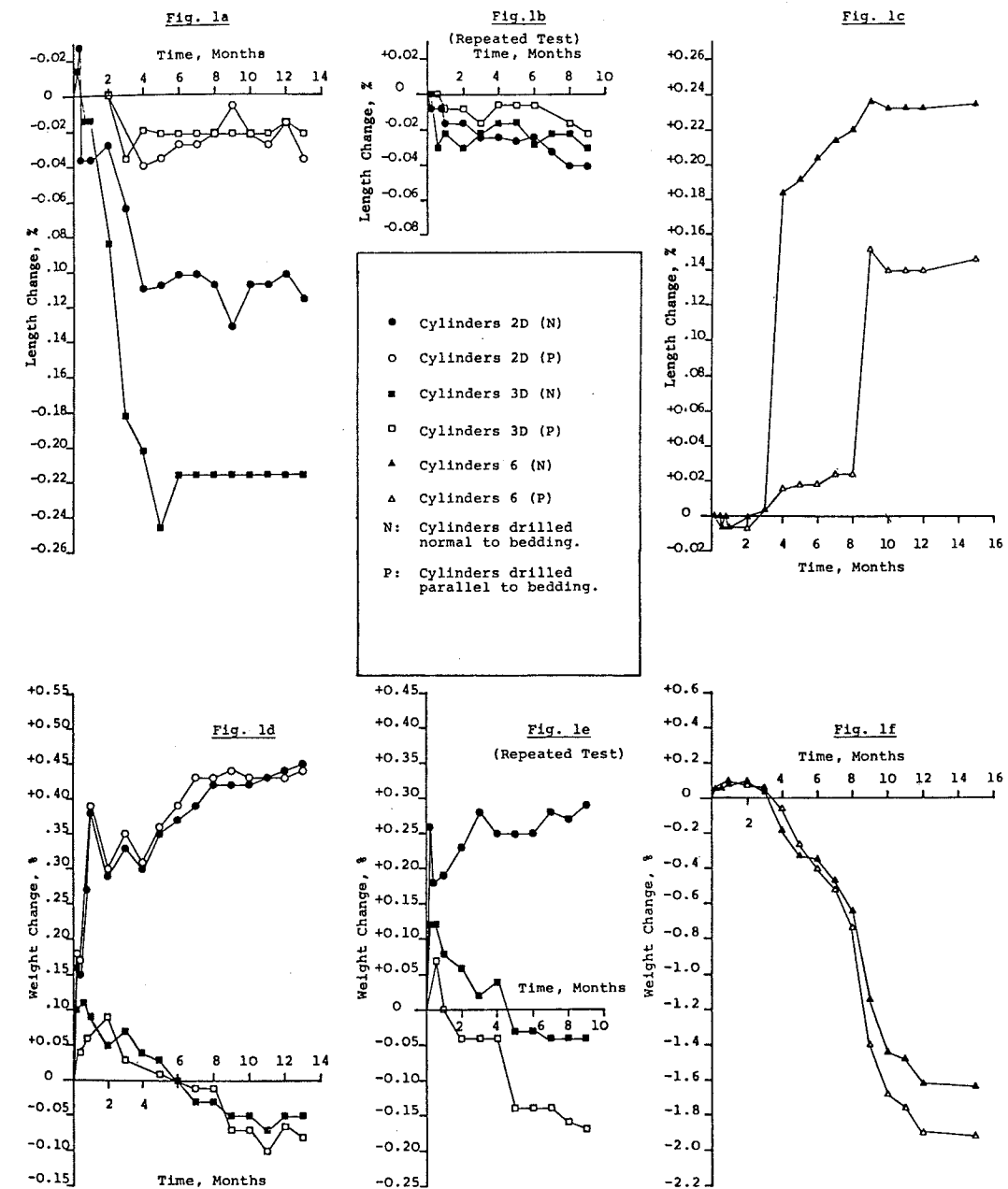
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FIGURE 1. Length change % versus time la, lb, lc. and weight change % versus time ld, le, lf.



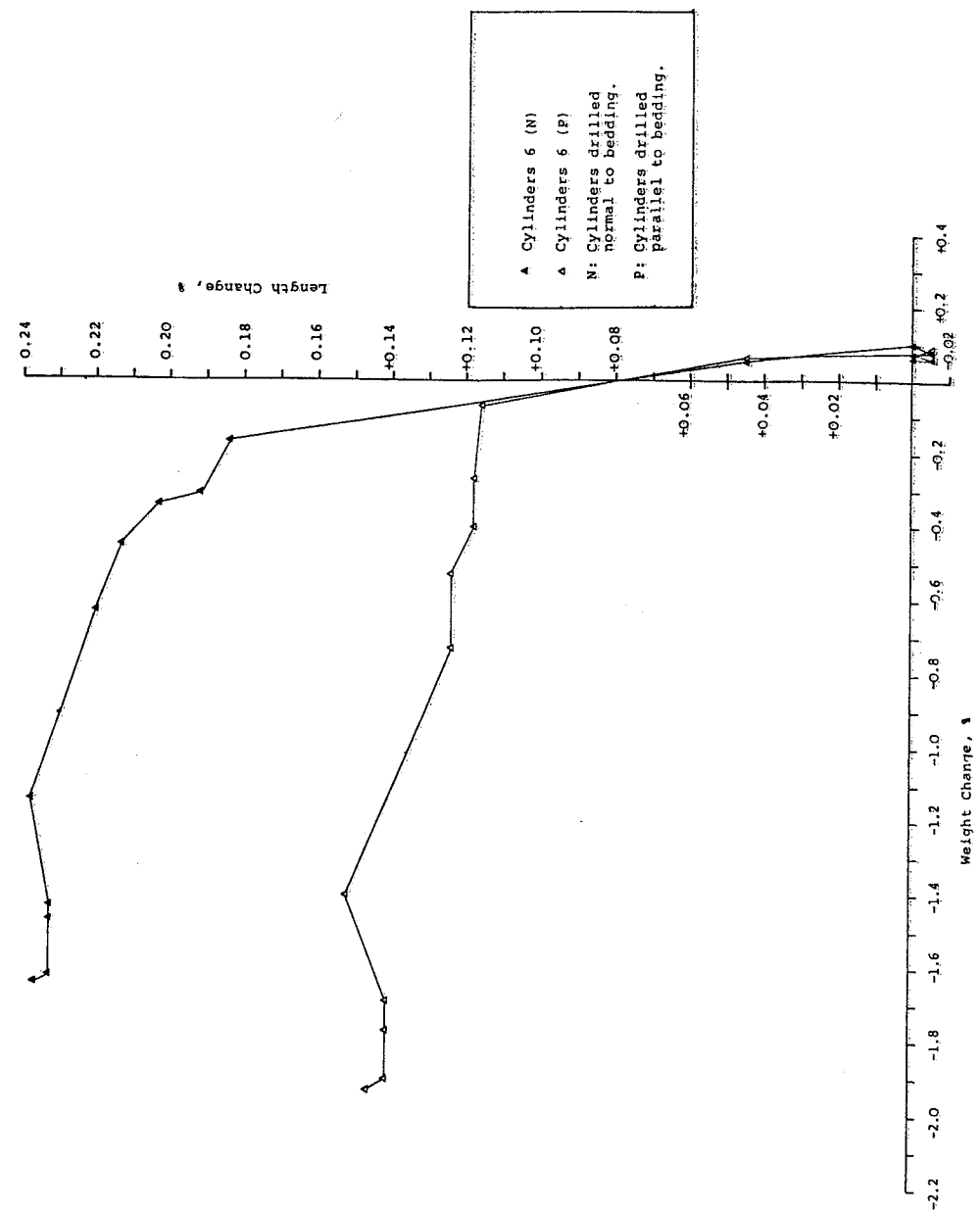
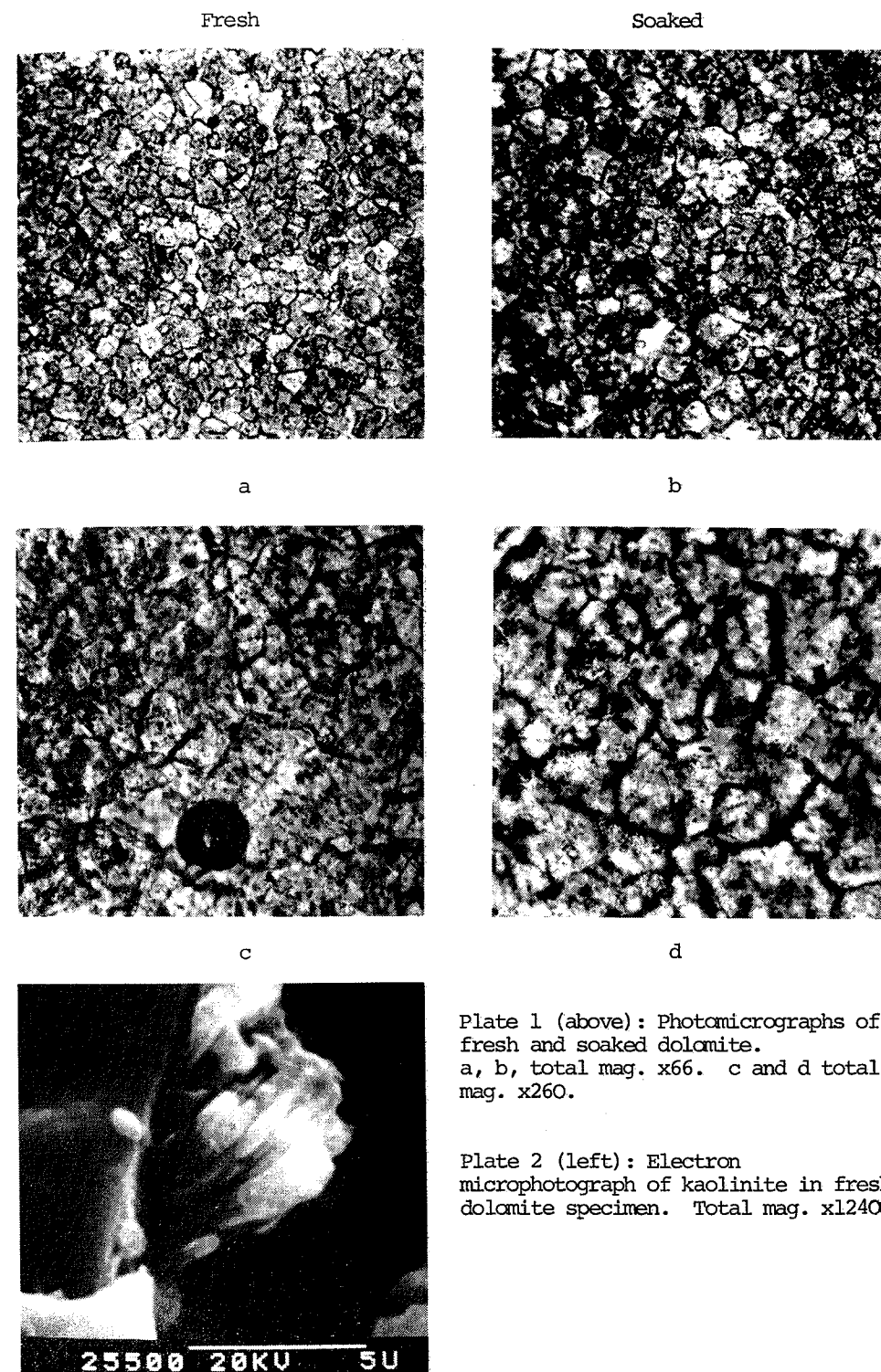
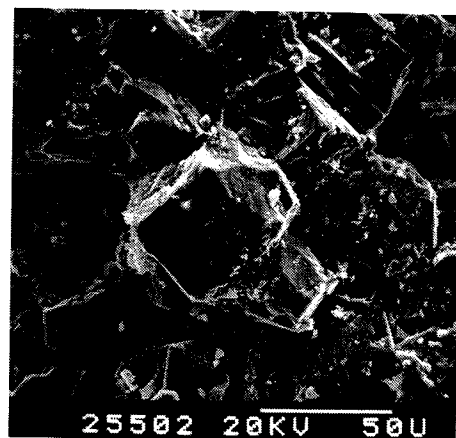


FIGURE 2. Length change % versus weight change % for the dolomite (6) rock cylinders.

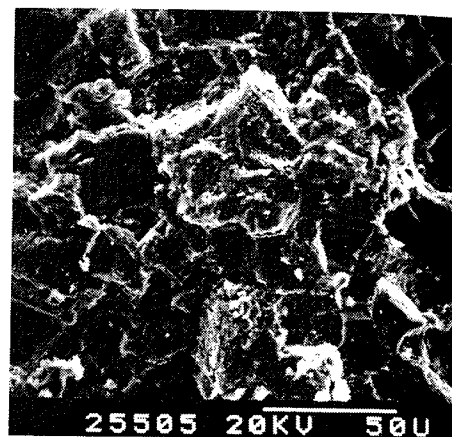


Fresh



a

Soaked

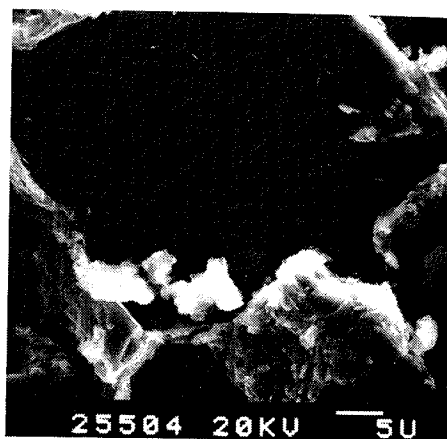


b

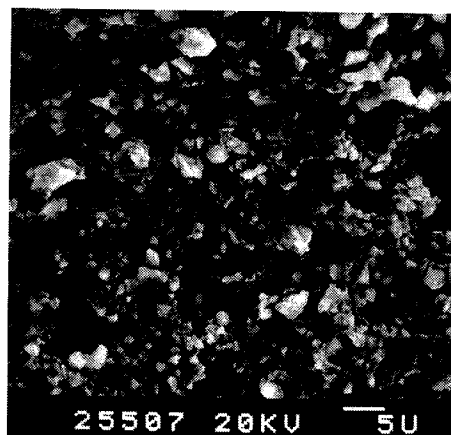
Plate 3 (above): Electron microphotograph of fresh and soaked dolomite.

Plate 4 (right): Electron microphotograph of a dolomite crystal in soaked specimen exhibiting calcitic centre and dolomitic periphery.

Plate 5 (below): Electron microphotographs of fresh and soaked limestone.

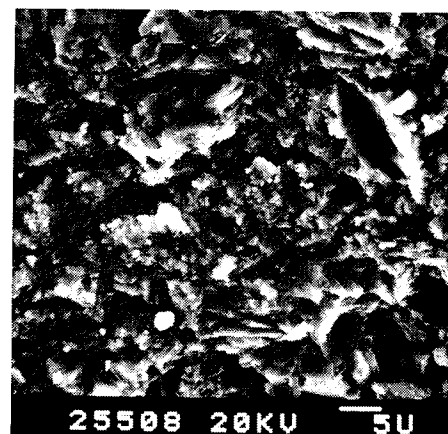


Fresh



a

Soaked



b

OSMOTIC CELL TEST TO IDENTIFY
POTENTIAL FOR ALKALI-AGGREGATE REACTIVITY

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1. ABSTRACT

1.1.1 An osmotic cell procedure for evaluating potential for deleterious reactivity of aggregates is described. A test criterion relating flow rate in the test to known performance in concrete is developed. The test is relatively rapid and inexpensive to run, and is not labor-intensive. Additional work is underway to further extend applicability of the procedure.

KEYWORDS: Alkali-silica reactivity, concrete, osmotic cell, rapid test.

2. INTRODUCTION

2.1.1 The durability of many concrete structures depends on the adequacy of tests to detect potential for alkali-silica reactivity. In the United States, the most widely accepted test procedures used for this purpose are:

- 1) ASTM Designation: C227-81 Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
- 2) ASTM Designation: C289-81 Standard Test Method for Potential Reactivity of Aggregates (Chemical Method)
- 3) ASTM Designation: C295-79 Standard Practice for Petrographic Examination of Aggregates for Concrete.

2.1.2 These tests have been used successfully for many years, either alone or in combination, to judge the suitability of an aggregate for use in making durable concrete. However, they all have certain limitations. In particular, many slowly reactive aggregates have been found to be innocuous in mortar bar tests that have been run for more than one year.⁽¹⁾ In addition, the tests can be labor-intensive and require the services of technically skilled personnel. They also can have limited applicability because of the particular mineralogical make-up of the aggregate sample.

2.1.3 It would therefore be useful to have a simple, relatively rapid, and inexpensive procedure that can identify deleteriously reactive materials without the limitations noted above. Exploratory work indicates that an osmotic cell procedure shows promise of fulfilling this need. Studies thusfar have been carried out primarily on homogenous materials known to be either deleteriously reactive or non-reactive in field and laboratory concretes and mortars. A description of the procedure and interim results are given below.

3. TEST METHOD

3.1.1 The apparatus used for this test procedure is known as an osmotic cell. It was developed more than 25 years ago by Verbeck and Gramlich at the Portland Cement Association Laboratories.⁽²⁾ The cell was used in their work primarily to elucidate the mechanism of expansion resulting from alkali-silica reactivity, and to identify factors that determine whether expansive or non-expansive reactions will occur. Most of their tests were run using opal as the reactive material. However, they also recognized that