MASONRY:

MATERIALS, PROPERTIES, AND PERFORMANCE

J. G. Borchelt, *editor*

ASTM STP 778

MASONRY: MATERIALS, PROPERTIES, AND PERFORMANCE

A symposium
sponsored by ASTM
Committees C-7 on Lime,
C-12 on Mortars for Unit Masonry,
and C-15 on Manufactured Masonry Units
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Foreword

The Symposium on Masonry: Materials, Properties, and Performance was held in Orlando, Florida, on 9 December 1980. ASTM Committees C-7 on Lime, C-12 on Mortars for Unit Masonry, and C-15 on Manufactured Masonry Units sponsored the meeting. J. G. Borchelt, Masonry Institute of Houston-Galveston, and Ken Gutschick, National Lime Association, served as chairmen. Mr. Borchelt has edited this publication.

Related ASTM Publications

Compilation of ASTM Standards: Concrete Masonry Units, 1979, 06-315079-07

Masonry: Past and Present, STP 589 (1975), 04-589000-07

Cement Standards—Evolution and Trends, STP 663 (1979), 04-663000-07

Concrete Pipe and the Soil Structure System, STP 630 (1977), 04-630000-07

Living with Marginal Aggregates, STP 597 (1976), 04-597000-07

Significance of Tests and Properties of Concrete and Concrete-Making Materials, STP 169B (1978), 04-169020-07

Compilation of ASTM Standards in Building Codes, 19th Edition, 1981, 03-001981-10

A Note of Appreciation to Reviewers

This publication is made possible by the authors and, also, the unheralded efforts of the reviewers. This body of technical experts whose dedication, sacrifice of time and effort, and collective wisdom in reviewing the papers must be acknowledged. The quality level of ASTM publications is a direct function of their respected opinions. On behalf of ASTM we acknowledge with appreciation their contribution.

ASTM Committee on Publications

Editorial Staff

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Introduction

This symposium is the third of a series started in 1974. It represents the combined activities of the individual ASTM committees with an interest in the masonry industry: C-7 on Lime, C-12 on Mortars for Unit Masonry, and C-15 on Manufactured Masonry Units.[1] Additionally, representatives of C-1 on Cement, C-18 on Natural Building Stones, and E-6 on Performance of Building Constructions were invited to participate. Thus all ASTM committees working with the masonry industry were involved.

The previous two symposia dealt with the history of existing specifications for masonry materials and test methods. Papers relating to then-current testing and research programs were included. *Masonry: Past and Present, ASTM STP 589,* published in 1975, was a result of the first symposium. Although no such volume was prepared from the second symposium, held in June 1976, several presentations did appear in the *Journal of Testing and Evaluation.*

Masonry: Materials, Properties, and Performance provided a forum for current research on masonry units, mortar and grout and their components, and masonry assemblages. The majority of the papers deal with the performance of the assemblage of masonry units and mortar. Thus the existing component specifications, covered in the earlier symposia, are viewed in the manner of use.

This represents a significant step in the masonry standards area. No longer are the individual materials regarded as separate elements. Rather, the performance of all the materials together is considered important. Obviously the performance of the masonry wall will result in changes to the standards written by ASTM committees working on the materials making up the wall. Discussions at the subcommittee and task group level currently reflect this fact. Task groups in ASTM Subcommittees C12.03 and C15.05 are currently writing practices that address these issues.

This publication contains information of interest to persons specifying and designing masonry construction. With its emphasis on the performance of

[1]Committee liaisons were (for C-7 on Lime) K. A. Gutschick, National Lime Association, Arlington, Va., and Jim Eades, University of Florida, Gainesville, Fla.; (for C-12 on Mortars for Unit Masonry) J. T. Conway, Santee Portland Cement, Holly Hill, S. C., and John Grogan, Brick Institute of America - 9, Atlanta, Ga.; and (for Committee C-15 on Manufactured Masonry Units) J. Gregg Borchelt, Masonry Institute of Houston-Galveston, Houston, Tex., and Joe Edwards, General Shale Products, Johnson City, Tenn.

walls it is especially valuable to those selecting the masonry materials to combine on a particular project. Problems of existing construction are delineated and recommendations given. Changes in material specifications and test methods may result from the information given in these reports.

J. G. Borchelt

Masonry Institute of Houston-Galveston, Houston, Texas; symposium chairman and editor

Materials and Masonry Components

J. I. Davison[1]

An Autoclave Expansion Test Method for Type N Hydrated Lime Intended for Use in Masonry Mortar

REFERENCE: Davison, J. I., **"An Autoclave Expansion Test Method for Type N Hydrated Lime Intended for Use in Masonry Mortar,"** *Masonry: Materials, Properties, and Performance, ASTM STP 778*, J. G. Borchelt, Ed., American Society for Testing and Materials, 1982, pp. 5–14.

ABSTRACT: This paper reviews the attempts of ASTM Committee C-7 on Lime to develop an acceptable method of assessing the expansive potential of unhydrated MgO in Type N hydrated lime in masonry mortar. Autoclave expansion tests on bars of mortar containing hydrated lime, portland cement, and aggregate are rejected because of variable results. A new test method has been developed in which autoclave expansion values for pressed tablets are more consistent and are considered more realistic in terms of field performance.

KEY WORDS: hydrated lime (Type N), dolomitic, autoclave expansion, unsoundness, tablets (compacts), masonry mortar, cementitious materials, measurement, acceptability

The development of a soundness test for hydrated lime has been a priority project of ASTM Committee C-7 on Lime for many years. ASTM Specification for Hydrated Lime for Masonry Purposes (C 207) includes a Type N (normal) and a Type S (special) hydrated lime. The requirement for a maximum limit of 8 percent on unhydrated oxides ensures soundness for Type S hydrates, but there is no restriction for Type N hydrates. This is a matter of concern to masonry consumers who are interested in minimizing sources of expansion in materials that have the potential to initiate disruptive expansions in masonry mortar. The current edition of ASTM Specification for Mortar for Unit Masonry (C 270) permits the use of Type N hydrated lime "if shown by test or performance record to be not detrimental to the soundness of mortar." This paper reports the development of an autoclave expansion

[1]Retired Research Officer, Division of Building Research, National Research Council of Canada, Halifax, Nova Scotia, Canada.

method that appears capable of predicting the expansive potential of Type N hydrates in masonry mortar.

The Problem

Dolomitic quicklime is by nature much more difficult to slake than high-calcium lime. Over a period of time and under the right conditions of temperature and humidity, unhydrated particles of MgO, which may now be located in the mortar in a masonry wall, may hydrate. The expansive potential is illustrated by the fact that the hydration of 1 mol of MgO to $Mg(OH)_2$ is accompanied by an increase in the molar volume of 117 percent. Since the introduction of pressure hydration in 1940, Type S hydrates with a maximum limit of 8 percent for unhydrated oxides have appeared on the market; these hydrates now make up over 90 percent of the lime used in mortar in the United States. It is not possible, however, to reduce the unhydrated oxides in dolomitic quicklime to the 8 percent level by normal hydration procedures. Despite this, Type N dolomitic hydrates, combined with portland cement in masonry mortars, have a long record of satisfactory field performance in Canada and the United States. The method of burning the lime can influence the hydration, and manufacturers marketing the product have adopted procedures designed to minimize the expansive potential. The satisfactory field performance of the Type N dolomitic hydrates is explained by the restraint provided by the strength developed in the matrix of the mortar [*1*] and the masonry wall [*2*].[2] A combination of these restraints is apparently sufficient to contain any stresses accompanying the hydration of MgO in Type N hydrates currently on the market. The problem, then, has been to develop a method capable of providing data relative to field performance, that is to say, a test capable of identifying products with expansion potentials that cannot be controlled by the restraints imposed by their service environment.

Bar Tests

A paper published in 1938 [*3*] describing preliminary considerations of test methods for a specification for masonry mortar includes discussion concerning the merits of an autoclave expansion test for bars of mortar containing lime. During the early 1940s, studies of an autoclave expansion test on mortar bars containing cement, lime, and sand, or cement and sand were under way at the Massachusetts Institute of Technology [*4*]. Later Wells et al [*5*] developed a method based on autoclaving 0.025 by 0.025 by 0.25 m (1 by 1 by 10 in.) cement-lime bars. There were problems in obtaining reproducible results with these methods, partly because of a lack of understanding of the reactions taking place during autoclaving.

[2]The italic numbers in brackets refer to the list of references appended to this paper.

In 1965 Ramachandran et al [*6*] published "An Unsoundness Test for Limes without Cement". In this method, compacts measuring 0.032 m (1.25 in.) in diameter were made by subjecting powdered lime, placed in a steel mold, to a pressure of 88.9 kN (20 000 lbf). The compacts were then autoclaved at 2034 kPa (295 psi) for 3 h, and the resulting expansion was calculated as the increase in the diameter of the sample. This method eliminated the complication of the unpredictable reaction with cement during autoclaving of bars and took less time than the bar method. However, the expansion values obtained, 14.5 to 18.5 percent, were much higher than those obtained with the bar method, about 5 percent, and were considered misleading in terms of the field performance of mortars containing the limes.

ASTM Committee C-7 Method

In 1969 requests for an expansion test from Committee C-12 on Mortars for Unit Masonry, during an attempted revision of ASTM C 270, resulted in a review of existing methods. The review indicated that the compact (tablet) method was potentially the best, and the development of a modified test began. In effect the Ramachandran test was modified to use tablets (compacts) containing a 1:1:6 cement-lime-aggregate mixture instead of lime alone. The change was made in order to obtain a more realistic assessment of the potential expansion caused by lime in a masonry mortar.

The method was approved in 1975 and is now included in ASTM Physical Testing of Quicklime, Hydrated Lime and Limestone (C 110). In this method, tablets 0.032 m (1.25 in.) in diameter and 0.006 m (0.25 in.) thick are prepared by subjecting mixtures of dry material to a pressure of 88.9 kN (20 000 lbf). The tablets are then autoclaved at 862 to 1034 kPa (125 to 150 psi) for 2 h, and the expansion is calculated by subtracting the expansion of a "standard" tablet from that of the test tablet. The "standard" tablet contains standard portland cement and standard aggregate, while the test tablet contains the same cement and aggregate plus the lime being tested in a 1:1:6 mixture. Type I or Type II portland cements are designated as standard cement, and pulverized limestone, minus 212-μm (No. 70) sieve, is designated standard aggregate. Limestone was selected because of the need for an aggregate with a low silica content to prevent pozzolanic reactions that could give false results.

Recent Studies

Since 1975, Subcommittee C07.09 on Research has continued efforts to upgrade the method because of concerns arising from variable results obtained by participating laboratories in successive round-robin studies. Data from successive studies involving a variety of limes and a number of laboratories have been subjected to statistical analyses in accordance with the guidelines

of ASTM Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials (C 802). The analyses underlined unacceptable variations in the data and have resulted in a major revision of the method. The revised method will shortly replace the 1975 version in ASTM C 110.

In the revised method the size of the tablets is increased to 0.057 m (2.25 in.) in diameter. There are two reasons for this change: (*1*) the statistical analyses indicated more consistent results with the larger tablet, and (*2*) the larger tablet is more convenient for use in the Popping and Pitting Test for Hydrated Lime used in plaster. This test, also included in ASTM C 110, references the Autoclave Expansion Test.

The mixture of cement, lime, and aggregate is essentially the same as that in the present method. However, portland cement and limestone are now considered standard if the autoclave expansion of tablets containing a mixture of these materials and reagent grade calcium hydroxide (instead of the hydrated lime) is less than 0.2 percent.

Under the new procedure a quantity of cement, lime, and aggregate sufficient to produce one tablet is mixed with 10 g of water. The water is used as an aid in obtaining a stable tablet; without some moisture the tablet may disintegrate after pressing. Any excess water will be extruded during the pressing operation and will be absorbed by a filter paper disk placed between the tablet and the mold plunger.

Six tablets are required; in the interest of consistency a separate batch of material is mixed for each tablet. The tablets are formed by placing the mortar mixture in the mold and applying a pressure of 33.4 kN (7500 lbf) for 10 s, then increasing the pressure to 88.9 kN (20 000 lbf) and holding for 10 s before releasing. The mold and release jig are shown in Fig. 1.

After the tablets are removed from the mold, three diameter lines are drawn across the surface of each tablet with a soft lead pencil; two diameters are normal to each other and the third bisects one of the 90-deg angles made by the first two lines. All six tablets are then placed in a plastic bag, heat-sealed, and cured overnight in an oven at 60°C ± 3°C (140°F ± 5.5°F).

The curing conditions are considered important. They permit the tablet to develop early strength and they also permit a certain amount of expansion that will not show up in the final expansion measurement. This is considered to be consistent with reactions that occur in field usage of Type N hydrated limes. Limes that might cause expansion problems in masonry applications will withstand the curing conditions and show up later in the autoclave treatment.

After curing, the tablets are allowed to come to room temperature and their diameter measurements are recorded with a length comparator as described in ASTM Specification for Apparatus for Use in Measurement of Length Change of Hardened Cement Paste, Mortar, and Concrete (C 490), except that the instrument is adapted so that measurements can be made in a horizontal position (Fig. 2).