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Ritchie, T.

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MASONRY MORTAR

By

Thomas Ritchie

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MASONRY MORTAR

by Thomas Ritchie, P.Eng.

A DICTIONARY definition of mortar states that it is a "mixture of lime, sand and water for joining stones or bricks". The latter part of this definition, which deals with the function of mortar is acceptable; that part dealing with composition, however, if it is to be satisfactory must be enlarged to take account of the many materials other than lime, or those used in combination with lime, that have come into use in Canada as cementing materials in masonry mortar.

Although the proportion of mortar in unit masonry is relatively small, (in the case of brickwork being at the most about 25 per cent of the volume, for example,) the influence it has on the performance of the masonry is usually far greater than this might indicate. It is well known that problems that arise in unit masonry walls, such as rain penetration, cracking, and efflorescence, can be directly attributed in many instances to the use of unsuitable mortar. The purpose of this paper, therefore, is to review the development of various types of mortars and mortar materials and to discuss the influence of mortar properties on the performance of unit masonry walls.

There is no doubt that the stone and brick buildings erected in the early days of settlement in Canada were built with mortar composed of lime, sand, and water, thus conforming to the definition mentioned previously. Just as local stone quarries, small brickyards, and sawmills, were established in the early settlements throughout Canada to supply the needs of building construction, so also were lime kilns operated to provide the material for mortar and plaster. In these simple kilns, the limestone was burned by wood to produce quicklime, which was then "slaked" into paste or putty for use in mortar. Needless to say, the numerous early buildings still in use in many parts of Canada after a hundred or more years of service attest to the usefulness of this type of mortar, and lime continues to be an important mortar ingredient. Other materials however, have come into use as well.

Hydrated Lime

The manufacture of lime underwent changes early in the 20th century when the production of "hydrated" lime was started. In addition to supplying quicklime, which had to be slaked to putty for use in mortar, lime plants also supplied a dry powdered form of lime, "hydrated" lime, which did not require slaking before use.

The "natural rock" cement industry was developed in Canada in the latter part of the 19th century. Through the burning of impure clay-containing limestones this industry produced hydraulic cements, which found some use in masonry mortar, sometimes in combination with lime. The natural cement industry later was replaced by the portland cement industry. Portland cement became, early in the 20th century, the basis of the major construction material, concrete, and it came to be used also in masonry mortar, sometimes in combination with lime.

In recent years another type of cementing material for mortar, called masonry cement, has been marketed. It is sold as a fine, dry powder which is mixed with sand and water in certain recommended proportions to produce mortar. Two general compositions of masonry cement are produced in Canada. One is an interground mixture of portland cement and limestone, while the other is a blend of portland cement and finely powdered hydrated lime. Each type usually contains small amounts of other substances (such as airentraining agents) to promote plasticity and workability. Certain fine-grained mineral substances such as clay are also produced in some areas of Canada for use in masonry mortar, being usually mixed with portland cement, sand, and water to make mortar.

It can be seen from this brief review that masonry mortar has developed from the early simple lime and sand composition (which continues to be used in Canada, but probably to a relatively small extent) to many other compositions made up of a variety of materials. The cementing materials most extensively used at present are probably a combination of portland cement and lime, or masonry cement.

Specifications have been pre-

Thomas Ritchie graduated, in engineering, from the University of Toronto, in 1949, and joined the Division of Building Research of the National Research Council shortly afterwards, where he has undertaken studies of problems of unit masonry construction.

Mr. Ritchie is a member of several C.S.A. and A.S.T.M. technical committees concerned with the preparation of specifications for masonry materials.

pared by the Canadian Standards Association and by the American Society for Testing Materials for most of the materials commonly used in masonry mortar. The latter organization has prepared in addition a specification for masonry mortar (Designation C270-57T), which applies to "mortars for use in the construction of unit masonry structures".

In order that a particular mortar shall comply with the specification, it must first of all be composed of certain materials such as portland cement, portland blast-furnace-slag cement, masonry cement, quicklime, hydrated lime and aggregate, all of which are covered by an A.S.T.M. Specification. Water used must be "clean and free of deleterious amounts of acids, alkalies or organic materials". As a second requirement the particular mortar must comply either with provisions of the specification which limit the proportioning of the cementing materials and sand, or with provisions governing the minimum compressive strength value of the mortar when tested in the form of 2-inch cubes at age 28 days. Five types of mortar, designated by letters "M", "S", "N", "O", and "K", are listed in the specification.

DESIGNATION OF MORTAR ON THE BASIS OF COMPRESSIVE STRENGTH (A.S.T.M. (270-57T))

Mortar Type	Average Compressive Strength (28 days) psi
M	2500
S	1800
N	750
O	350
K	75

Table 1.

MORTAR DESIGNATION BASED ON COMPOSITION (A.S.T.M. C270-57T)

Mortar type	Parts by Volume of Portland cement	Masonry cement	Hydrated lime or lime putty	Aggregate, measured in a damp, loose condition
M	1	1 (type II)	——	Not less than 2¼ and not more than 3 times the sum of the volumes of the cements and lime used.
	1	——	¼	
S	½	1 (type II)	——	
	1	——	over ¼ to ½	
N	——	1 (type II)	——	
	1	——	over ½ to 1¼	
O	——	1 (type I or II)	——	
	1	——	over 1¼ to 2½	
K	1	——	over 2½ to 4	

Table 2.

Compressive Strength

The compressive strength of the mortar determines the designation by reference to the values in Table I. The mortar is prepared in the laboratory, mixed to a certain consistency or "flow" and in proportions of cementitious material to sand of between 1:2¼ and 1:3½.

Composition

As an alternative method of determining the mortar designation, a "composition" table has been provided, the designation being given by the proportions of the materials used, as set out in Table II.

To comply with the specification, a particular mortar must either possess a certain minimum compressive strength or, alternatively, must conform to certain proportioning of ingredients. In both cases an additional requirement is that the mortar have a water retention value exceeding 70; the significance of this property is discussed later.

Although five types of mortar are listed in the specification, there is no differentiation made among them unfortunately with regard to their use. In using the specification, therefore, several questions may arise concerning the basis for specifying a particular mortar from the five listed, the conditions under which one type of mortar is to be preferred to another, and the special properties (if any) that a certain type may contribute to masonry. These questions lead into the complicated matter of the influence of mortar properties on various properties of unit masonry walls of which strength, stability, and weather resistance are of particular importance.

A masonry wall may be considered to have two main functions. In the first place it must support the structural loads placed on it, such as those of roof and floors, and those of lateral forces such as wind pressure; secondly, it must provide the interior of the building with some degree of protection from the weather. Since these are continuing functions, some degree of durability of the masonry is also required.

Many studies have been reported on the relationship between strength of units, strength of mortar, and the resulting strength of the combination. The resistance of masonry to compressive and to lateral or transverse stresses varies greatly depending on the type of mortar used. The properties of the unit used, and the techniques used in combining unit and mortar have also an important influence on the resulting strength.

Strength of Unit Masonry

The dependence of the strength of unit masonry on both the strength of the mortar and the strength of the unit is recognized in most building codes, including the National Building Code of Canada. If a unit having a particular compressive strength is used, there is a range of permissible stress values per unit area of the masonry made of it, depending on the type of mortar used. Likewise, if a particular mortar is selected, there is a range of permissible stress values per unit area of the masonry, depending on the strength of unit used. The designer therefore has a means of reducing to some extent the thickness of sections of masonry by the selection of certain combinations of units and mortar. The National Building Code sets out in addition minimum thickness values of walls for various uses and heights. If these minimum thickness values

are followed, it is usually unnecessary to design the combination of unit and mortar according to calculated stresses in the masonry.

For conditions of unusually severe stresses on unit masonry, such as occur in buildings that are subjected to earthquake shocks, special mortars and mortaring grouts along with specially designed reinforcing systems for unit masonry construction have been developed to ensure satisfactory performance of the walls. Reinforced brick masonry construction, for example, is extensively used in the earthquake zones of the United States. For this type of construction mortar of special properties is required, and an A.S.T.M. specification for it has been prepared (Designation C161-44T).

The strength of masonry is usually increased as the strength of mortar is increased, but strength beyond that needed for the structural adequacy of the masonry usually has no value. Conforming with the view that "stronger masonry is better masonry", very strong mortars have sometimes been used, often with adverse effects on other important properties of the masonry. The "shrinkage cracking" problem may provide a useful illustration of this interdependence of the properties of unit masonry.

All masonry materials react to changes in moisture content by swelling or shrinking, but the extent of the dimensional change varies greatly depending on the type of material. The "drying shrinkage" of concrete and sand-lime bricks, for example, is generally considerably higher than that of burnt clay bricks, but for concrete bricks it may be reduced appreciably if in their manufacture they are treated by high steam pressure in an autoclave.

Experience of the Building Research Station of Great Britain has indicated that if concrete and sand-lime bricks of "normal" drying shrinkage are used in combination with a very hard, strong mortar, there may be sufficient restraint by the mortar, opposing the shrinkage of the bricks as they dry, to cause cracks in the wall. With weak mortar, however, which has more "give", the shrinkage of the bricks will be less restrained and the danger of cracking is accordingly reduced.

British Standards

The specification of the British Standards Institution for concrete and sand-lime bricks recognizes that mortar must be carefully selected with regard to the amount of drying shrinkage of the bricks; it contains a list of mortars suitable for use with bricks of various drying shrinkages. Applying these mortar compositions to the types listed in the A.S.T.M. specification, it would appear that only mortar types "O" and "K" would be considered desirable for use with concrete and sand-lime bricks in relation to the danger of shrinkage cracking. In order to secure unusual load-bearing capacity of a wall made of such units, however, one of the other types of mortar may have to be used, and this gives rise to the situation of satisfying the requirement for one property of the masonry while probably producing a deficiency in another.

The ability of unit masonry walls to resist the penetration of rain is another quality that depends in large measure on the properties of the mortar used. Other factors are of importance as well, such as the properties of the unit used and the manner in which unit and mortar are assembled into masonry.

Bricklaying

The problem of moisture penetration of brick masonry has received a great deal of study, both in Europe and North America. It may be noted from these studies that in most cases of moisture penetration of brickwork, water passes through unbonded areas between brick and mortar. It is generally believed that the passage of water through the brick itself, or through the body of the mortar, does not occur in sufficient quantity to contribute to the problem, except under unusual conditions. Moisture penetration is therefore associated with the interface condition between brick and mortar.

If the mortar and brick have such properties that when they are brought together there is complete extent of bond over the entire surface, with no unbonded areas between brick and mortar, then the joint should be resistant to moisture penetration. The ability of a particular brick and a particular mortar, when used together, to form a complete extent of bond is governed in large measure by the rate of water absorption of the brick, and by the water retention properties of the mortar.

Moisture Penetration

In the operation of bricklaying, a bed of mortar is spread on a course of bricks. As soon as the mortar is placed on the bricks, there is a withdrawal of some of its moisture into the bricks. The rate of withdrawal depends on the rate of absorption or "suction" of the bricks. One type of brick, for example, when placed in water to a depth of ⅛ inch for one minute (the standard test condition to determine "suction") may absorb less than 5 grams of water, whereas another type of brick may take up more than 100 grams. The rate of water movement from the mortar to the brick course on which it is placed depends also on the "water retention" value of the mortar, which is a measure of the ability of mortar to resist loss of water to an absorbent brick. This property is also determined by a standard test. The "suction" of the brick and the "water retention" value of the mortar together determine the plasticity and adhesiveness of a bed of mortar when a brick is placed in it, and thus determine also the completeness of the bond between brick and mortar. If a mortar of high "water retention value" is placed on a course of absorbent bricks, it will probably remain plastic and adhesive until a brick is placed in it. A complete extent of bond is thus achieved, whereas incomplete bond will probably result from the use of a mortar of low "water retention value", under the same conditions.

The water retention value of mortar is not directly related to strength. For cement-lime mortars, however, relatively strong mortars which are high in Portland cement content are generally low in water retentivity; so also are mortars of masonry cements. Relatively weak mortars, on the other hand, which are high in lime content, are generally high in water retentivity. The properties of the lime used have a great influence; putty from slaked quicklimes usually

produces mortars of highest water retention values.

When a particular brick or other unit has been selected for use in masonry, the mortar chosen must provide adequate structural properties of the wall and adequate resistance to moisture penetration. This last-mentioned property is doubly important since it affects the durability of the masonry. At present general guidance only on the selection of mortars for a particular type of unit can be provided with respect to these requirements. In the case of brick masonry, the recommendations of the brick manufacturer regarding a suitable mortar should be carefully considered.

Significant

It may be shown that mortar plays a significant role in the problem of efflorescence on unit masonry although here again, as with many other problems, several factors have an influence on the result. Experience with the problem indicates that certain mortar compositions are less likely to be associated with the occurrence of efflorescence than others. In general, the use of portland cement in mortar introduces salts which very frequently are found in efflorescence, namely, sodium and potassium sulphates. Lime generally contains less of these salts; as lime is replaced by portland cement in mortar, therefore, a greater capacity for producing salts for efflorescence is built up. Masonry cements, which are composed in part of portland cement, similarly contain salts which may form efflorescence. Both portland cement and masonry cement, however, may be specially manufactured to be very low in alkali content, and therefore to have minimum capacity to contribute salts of efflorescence to masonry.

Important Properties

A short review of the development of mortars for unit masonry has been presented, along with some notes on a current specification for mortar. Important properties of unit masonry are structural adequacy an weather resistance. The influence of mortar properties on these qualities of unit masonry has been discussed and it has been noted that the selection of mortar should be made primarily in relation to the unit with which it is to be combined. No definite "rules" have apparently yet been established for the selection of mortar. Many research organizations, including the Division of Building Research of the National Research Council of Canada, are engaged in continuing studies of the role of mortar in the performance of unit masonry from which should come scientific information which, when combined with sound practical experience, should contribute significantly to the steady development of good masonry practice. ■