DISCUSSION

"Masonry Cements - A Laboratory Investigation - J. W. Ribar and V. S. Dubovoy

Comment (R. E. Klingner, University of Texas at Austin): In my opinion, this paper should deliver more specific information.

1) The following conclusions discussed in the Abstract are not sufficiently substantiated in the paper itself:

   a) "flexural bond in wall assemblies was generally in excess of 100 psi." This conclusion is insufficiently substantiated by Table 1, which refers to only one of the 11 types of brick mentioned in the paper. Table 2, which contains data for different types of brick, shows many instances of average strengths considerably below 100 psi. For example, Brick A has an average (of the averages) bond strength, across all Type S masonry cements, of 72.7 psi, with a coefficient of variation of 31%. Corresponding values for Brick F are 37.0 psi and 45%; and for Brick G, 69.9 psi and 34%. On this basis, the numbers presented in the paper do not seem to substantiate the authors' conclusion.

   b) "single-wythe wall assemblies exhibited satisfactory watertightness." Since neither the water penetration test nor the criteria used are identified, this statement by itself is not sufficiently convincing.

2) Flexural bond is usually increased by moist-curing prisms, rather than air-curing them. How were the prisms in this study cured? If they were moist-cured, that fact is significant, and should be specifically pointed out by the authors.

Answer (Jacob W. Ribar)

We are sorry that you find the paper lacking in specifics. As an afterthought we probably would present the data in a different format. However, this paper is itself an abbreviated version of Reference 4. In answer to the question in paragraph (2) the prisms were enclosed in plastic wrap for 7 days and air cured for 21 days.
DISCUSSION

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Question (J. H. Matthys, University of Texas at Arlington):

In the abstract it is stated that "regardless of composition of individual masonry cements, flexural bond in wall assemblages was generally in excess of 100 psi." By wall assemblies, do you mean prisms cut from the water permeance specimens or prisms built in the laboratory? In Table 1, which applies to only one of the 10 bricks evaluated, for the flexural bond strength of masonry prisms at 28 day irrespective of mortar type, 25% of the test gave bond strength less than 100 psi. The same information in Table 2 irrespective of masonry cement type indicates the following percentage of bond test values less than 100 psi: Brick A - 90% of tests; Brick B - 85% of tests; Brick C - 35% of tests; Brick D - 30% of tests; Brick E - 35% of tests; Brick F - 89% of tests; Brick G - 90% of tests; Brick H - 45% of tests; Brick I - 63% of tests; Brick J - 74% of tests; and Brick K - 25% of tests. Also in Table 3 60% of the brick tested gave average flexural bond strengths less than 100 psi. Obviously this data shows a significant portion if not majority of the 28 day prism tests to give bond less than 100 psi. Your statement seems to apply only to prisms cut from water permeance walls as given in Table 1 for Brick K only. If so, does your data for cut specimens from walls for the other nine bricks evaluated, which is not given in paper, show the same results?

In the abstract it is stated that "single-wythe wall assemblies exhibited satisfactory watertightness." The authors do not state whether the tests were conducted according to ASTM E514-86 or ASTM E514-74. If conducted according to ASTM E514-86, what is your reference point to indicate from your data the "satisfactory statement" since E514-86 does not give any such reference point?

Were the IRA of the bricks listed in Table 2 based on the "As Laid" condition or the "oven dried" condition? What is the IRA of Brick "K" which was the brick associated with all the data in Table 1, Table 4, and Figure 1? What is the contour ratio Rp of Brick K?

For the flexural bond strength of wall masonry at 28 day in Table 1 I assume this data is from specimens cut from the water permeance wall specimens. If so, how can this data be 28 day if the walls were subjected to
water permeance testing at 28 days for a 72 hour period? Were the prisms immediately cut from the 31+ day wet walls and immediately tested or allowed to dry first? Were the bond specimens cut from the top or bottom of the wall? What joints if any were tooled? If tooled, what was the position of tooled joints in bond wrench test? Was whitewash applied to the water permeance specimens? If so for bond specimens cut from wall, what was the position of whitewashed face in bond wrench test?

When you say solid clay unit, do you mean a unit with no holes whatsoever or a unit cored ≤ 25% of the gross area? Were all of the 10 brick types in your study cored?

The paper states "Type S and Type N masonry mortars were prepared in accordance with the proportion requirements of ASTM C270-88a. Bond strength test specimens were fabricated with these mortars. Initial flow of mortar was established by bricklayers (field flow). Mortar properties are shown in Table 4." Thus I assume Table A represents physical properties of field flow mortars proportioned by ASTM C270. For these field flow mortars, how were they cured—in laboratory air or moist room? Typical masonry cement mortar test data that I have seen show ASTM C270 laboratory mortar (Flow ≈ 110, moist cured) 28 day compressive strengths of 1900 to 5100 psi for Type S masonry cement mortars and 1200-1450 psi for Type N masonry cement mortars. On the other hand for field mortars (Flow ≈ 135, lab air cured), 28 day compressive strengths of 1400-3000 for Type S masonry cement mortars and 600-1200 for Type N masonry cement mortar. Was the same mortar sand used for all prisms and wall assemblages? What type of sand was used?

What was the construction and curing conditions for the flexural bond prisms? Stack bonded? Prisms wrapped? Prisms wetted? Prisms cured in lab air?

In your results Item 2 you indicate three characteristics: (a) bond strength from 65 to 211 psi, (b) 75% of mortar have bond strengths greater than 100 psi, and (c) no essential difference between bond strength at 14 days and 28 days. Although these characteristics may be appropriate for the masonry cements with Type K brick, they do not seem to be necessarily appropriate statements as a whole. For example the range of bond strength for the Brick Type A is from 18 psi to 140 psi while for the Brick Type F from 14 to 104 psi. The percentage of bond test values 100 psi or greater is only 10% for Brick A, 15% for Brick B, 65% for Brick C, 70% for Brick D, 65% for Brick E, 11% for Brick F, 10% for Brick G, 55% for
Brick H, 37% for Brick I, and 26% for Brick J. It appears that the significance of difference between 14 and 28 day strengths for Brick K is a function of the mortar. The percentage difference for Brick K ranges from 1% to 80%. Thirty-five percent of the Brick K tests have a difference between 14 and 28 day tests strengths of 30% or higher. What does this data for the other nine bricks show?

In your results Item 6 you point out as a whole that the average water leakage rate for the 72 hour test was lower than that measured during the first four hours. On the other hand Table 4 for Brick K indicates eight of the 10 Type S masonry cement mortars and seven of the 10 Type N masonry cement mortars give an increase in water penetration rate in the first four hours for the 28 day test as compared to the 14 day test. Why? For Table 4 how many walls per mortar were tested? Were the same walls tested at 28 days that were tested at 14 days?

In Figure 1 you plot average 72 hour water penetration versus bond strength of prisms cut from wall and generate a correlation coefficient of 0.38. Is it not true that this figure only plots Brick K data; i.e., the other nine sets of brick data are not plotted? Does the other brick data indicate the same results?

In discussion it is stated that the flexural bond strengths of specimens removed from wall assemblages were greater than bond strength on companion stack bonded prisms. In your Table 1 for Type N masonry cements, 60% of data indicate strengths of specimens from walls less than stack bonded prism? What do you attribute the difference in behavior between Type N and Type S masonry cement?

Answer (Jacob W. Ribar)  
Dr. Matthys As stated in the first sentence of "Results" on page 3 of the paper, "Complete results are summarized in Reference 4." However in answer to your question only Phases I and II of the research dealt with water penetration and hence only Brick K wall prisms were tested.

Your paragraph 2. Reference 4 states that E 514-74 was employed in this research.

Your paragraph 3. All references in our paper to evaluation of materials are based on the results of testing in accordance with ASTM standards. In this case ASTM C 67 "Standard Methods of Sampling and Testing Brick and Structural Clay Tile" Section 9, "Initial Rate of Absorption (Suction)" procedures were followed to establish data. See response to Mr. Walker for remaining questions in this paragraph.
Answer (Jacob W. Ribar) (continued)

Your paragraph 4. Dr. Matthys you are correct in your statement that our prisms were tested later than 28 days. We corrected this error in the footnote to Table I.

Specimens were removed from the upper or top portions of the wall. The concaved tooled joints on the face of the wall were tested in tension; therefore, the whitewashed face of the dried specimen was in compression.

Your paragraph 5. In Reference 4 we state that we used "solid (uncored) brick" or as you so aptly stated, "no holes whatsoever." You will also find that the total research effort employed eleven (11) brick, one (1) in Phases I and II and ten (10) brick in Phase III.

Your paragraph 6. No assumptions are necessary.

Table A is titled "Physical Properties of Field Flow Mortar Proportioned by ASTM C 270." Mortar cubes were cured in a moist cabinet. The sand from a single shipment was used for all phases of the research. I apologize for not knowing how to answer your question regarding the "type" of sand since ASTM C 144 "Standard Specification for Aggregate for Masonry Mortar" does not list aggregate by types. If you are referring to natural vs manufactured sand then our response is "natural".

Your paragraph 7, 8, 9, 10 and 11 are answered in "Reference 4".
DISCUSSION:

"Masonry Cements--A Laboratory Investigation: -
Jacob W. Ribar and Val S. Dubovoy

Question (Dan Walker, CHEMSTAR LIME Company):
Your paper does not give details concerning the materials used in the study or the conditions of test. Could you give a response to the following questions? The 20 masonry cements used (of nearly 100 produced in the country) were picked from various geographical areas, could you state the particular States each were manufactured? Was the same sand used in all the tests, and what was the source? Were the masonry units dampened before used in the prisms? You mention several physical parameters, but do not give the data. For example, what was the cement fineness, mortar water, air content, and water retention of each of the masonry cements or mortars?

In the DISCUSSION of your paper you..."suggest that, with good workmanship, values higher than those achieved from laboratory specimens are possible in construction." How can you be sure of this, when all your data was generated from laboratory conditions and workmanship?

Your Tensile Bond and Water Penetration tests were made on "brick K", but no IRA or Contour data is given for this brick. Would you explain this? Also, were the K Brick moistened before made into prisms? What ASTM method was used for the water penetration tests? Was the mortar for the water penetration tests made according to C 270 procedure, and if so, what type of mixer was used?

Answer (Jacob W. Ribar)
Mr. Walker all the details are not contained in the paper because of ASTM restrictions on the size of the document. It should be noted that the first paragraph in "Results" does state "complete results are summarized in Reference 4."

Your paragraph 2. Our research showed that prisms removed from wall assemblies yielded higher bond values than laboratory prepared prisms. With both assemblies constructed with the same materials and workmanship the conclusion that higher bond values can be achieved in-the-wall as opposed to field constructed prisms is valid.

Your paragraph 3. Your questions are again answered in Reference 4. The IRA of Brick K is shown on Table IV of that document as 9 grams. No contour data were
Answer (Jacob W. Ribar) (continued)
produced for Phases I and II where Brick K was used. Phase III studied the effects of various masonry units on flexural bond. Brick K was not "moistened."

Thank you for your interest and comments.
DISCUSSION

"Masonry Cements - A Laboratory Investigation" - Jacob W. Ribar and Val S. Dubovoy


The reviewers report on a well-conceived and well-executed experimental program to provide data on the bond of masonry cement mortars to clay masonry units and on the water penetration of brick masonry panels built with masonry cement. The observations in this discussion pertain to the flexural bond issue only.

Flexural bond strength is an important attribute which is related to performance limit states of masonry, e.g., moisture penetration through cracked joints and structural behavior, i.e., response to loads in a cracked or uncracked state. As masonry design practice becomes based upon limit state and probabilistic concepts in the future, properties such as flexural bond will have to be expressed in terms of expected values with their variation stated. Excessive variation will lead to lower "phi" factors and penalize the design. Even for today's working stress design approach, excessive variation of properties requires setting a lower minimum strength limit than may be desirable.

The results reported in Table 1 indicate that the coefficient of variation of 28-day cube strength is 22% for Type S masonry cement mortar and 37% for type N mortar. The coefficient of variation of 28-day flexural bond strength of the masonry prisms tested built with Type S masonry cement mortar is 36% and for those built with Type N mortar is 31%.

The results in Table 2 are themselves averages of 12 joints. The data was not presented (due to space limitations) to enable the variation to be evaluated. However, the coefficients of variation of these average values for the flexural bond strengths of prisms for bricks A, B, C, D, and E is as follows:
Based upon this data, it appears that, in general there is greater variability associated with Type N masonry cement mortar.

The reviewer's opinion is that the variations in properties revealed by this data is excessive especially considering that the masonry cement mortar and other specimens were prepared in a laboratory. There is evidence that flexural bond properties and cube strength of the specimens made from portland cement-lime mortars have coefficients of variation on the order of 20%.

Attainable target values of variation should be set perhaps in the 10%-15% range measures taken to obtain them. This would, of course, require a significant effort and degree of cooperation by producers.

**Answer (Jacob W. Ribar)**

Mr. Noland Thank you for your gracious compliment. Even though our research included 11 brick and 20 cements, as is always the case with research, it never seems to be enough. It would have been interesting to discover how the cement-lime mortars would have performed with the same materials used in our study.
DISCUSSION

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Results - In result No. 1, the authors state that flexural bond strength is a function of masonry cement physical parameters but that no single parameter was applicable to all masonry cements. This suggests that characterizing masonry cement performance using physical measurements alone is not reliable. Do the authors think a combination of measurement techniques, for example, chemical and physical, would improve one's ability to predict masonry cement bond behavior?

Concerning result No. 2, it should be noted that the values given are for brick K only. In Table No. 2, masonry cements with brick A vary from 18 psi to 140 psi and with brick G they vary from 58 psi to 130 psi.

In result No. 3, a comparison is made between specimens removed from wall assemblies and companion stack bond prisms. Wall assembly specimens were tested by C1072 and found to have higher strengths. These walls were first subjected to water permeance testing. The procedure calls for a preconditioning with water, and the test involves wall exposure to virtually the saturation point for 72 hours. What effect does this "wet cure" have on bond? Can your conclusion that wall bond performance is greater than air cured prism performance be applied to walls which have been air cured according to the provisions of C1072?

In Table No. 1, bond performance at 28 days is 30% greater for Type N masonry cement mortar compared to Type S. Is this normally seen for masonry cement mortars? To what would you attribute this performance difference?

In result No. 5, the initial rate of absorption and surface texture of the brick are said to have had significant effects on bond. The reference is Table No. 3. There is no apparent correlation between flexural bond and the variables cited. Tables No. 1 and 2 contain bond values for all masonry cements with all bricks. These show wide variations in bond (C1072) for individual masonry cement mortars with different brick. For example, with brick K (Table No. 1), bond varies from a low of 45 psi to a high of 211 psi. Since the initial rate of absorption and surface texture are the same for all combinations in Table No. 1, what accounts for the variations? Bonds for masonry cement mortars with seven of the ten brick in Table No. 2 show the lowest being only 1/4 as strong as the highest. If brick IRA and surface texture are not the primary factors in creating bond variances with masonry cement mortar, what factors account for them in Table 2.

Discussion

In the second paragraph the statement is made that bond is affected equally by physical properties of masonry cement, mortar, initial rate of absorption and surface profile of the clay units. There is no evidence given supporting this conclusion. What are the correlation coefficients for each parameter?
In the third paragraph, the authors suggest that high IRA brick need to be dampened. This may be valid for masonry cement mortars. There is no data provided to support this statement for Portland cement-lime mortars. Where can supporting data be found which establishes the need for unit wetting with Portland cement-lime mortars?

Summary - The second paragraph contains a broad conclusion which is not supported by data. In the Results section (Result No. 2) the authors state that "good" bond was 100 psi or better. The chart below lists average bond strengths for each masonry cement mortar in combination with all brick.

<table>
<thead>
<tr>
<th>TYPE N MORTAR</th>
<th>Masonry Cement Designation</th>
<th>Average Bond (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4  7 11 12 13 17 25 26 34 47</td>
<td>64  85  59 120 99 88 113 55 74 96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE S MORTAR</th>
<th>Masonry Cement Designation</th>
<th>Average Bond (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2 6 30 41 43 49 50 54 56</td>
<td>110 67 74 86 82 87 113 87 98 96</td>
</tr>
</tbody>
</table>

Six Type S and six Type N masonry cements provide a mortar whose performance is at least 10% below the value chosen to represent good bond (100 psi). Is your conclusion based on the fact that each masonry cement produced at least one combination out of 10 that equalled or exceeded the 100 psi? If not, what are the criteria used to arrive at this conclusion?

Answer (Val S. Dubovoy)

Result No. 1. As stated in reference 4, masonry cement bond can be predicted more accurately on a multiple regression basis using physical properties of masonry cements and mortars. It can also be predicted on a multiple regression basis using brick physical characteristics, such as IRA and surface texture.

Result No. 2. The authors agree.

Result No. 3. We cannot conclude quantitatively as to what effect "wet cure" would have on flexural bond. It should be noted, however, that only the areas where moisture migrated through the wall during the entire test period were fully saturated, thus receiving the "wet cure" being referred to. Our results show that out of 20 sets of wall assemblages tested for water penetration, 9 sets exhibited wetted areas ranging from 2.7% to 8.1% of wall area.
Answer (Val S. Dubovoy) (continued)

8 sets - ranging from 10% to 29%, and only 3 sets of walls were fully saturated (see Table 4). These parameters were recorded just after 4 hours of testing - the time period generally associated with highest percentage wetted area before any "self-healing" and subsequent drying of the walls start taking place. Thus, in the majority of cases only limited areas of the wall assemblages received extra "wet cure." Furthermore, our results show wetted areas are generally located within first 8 inches near the edges of the wall assemblages. Had the "wet cure" been an influencing factor, samples removed from these areas would have exhibited bond strength higher or equal to that of the samples removed from the center of the wall assemblages which generally showed much less penetration of moisture. In reality just the opposite happened. The wall samples from center of the assemblies exhibited higher flexural bond. Therefore, it appears that "wet cure" received by the walls during the test does not affect bond.

Table 1 We do not have data to answer your question. Additional research into the properties of these cements would be required.

Result No. 5 Your statement is incorrect. The lowest bond value was 65 psi. The effects of initial rate of absorption and surface texture are discussed in great detail in Reference 4 where very good correlations were established between these two parameters and flexural bond on a multiple regression basis. As far as bond values in Table 1 and 2 are concerned, Table 1 gives the bond values for various masonry cements and the same brick. Table 2 gives the bond values for various brick and masonry cements. If you read Table 2 in only one direction, vertically, the influencing factor is brick. If you read Table 2 horizontally, the influencing factor is masonry cement. Hence, the conclusion stated in "summary" is that both brick and mortar have equal effect on bond.

Discussion
First paragraph - see Result No. 5, second paragraph - Brick Institute of America in its Technical Note 7B recommends wetting brick with IRA in excess of 30 g/min regardless of the type of masonry mortar.

Summary
This conclusion was based on the data in Table 1 where flexural bond is presented for various masonry cement mortars and one brick, thus showing effects of various masonry cements on bond.