# A NEW TEST METHOD FOR FLEXURAL BOND STRENGTH OF MASONRY PRISMS

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## ABSTRACT

As part of a comprehensive research program on bond strength at the University of Maryland, a modification to the ASTM E 518 flexural bond test has been developed using a loading sleeve. The loading sleeve allows the testing in direct flexure of all joints of a masonry prism. The results of a pilot test program to compare the results of flexural bond tests of masonry prisms using the loading sleeve and the bond wrench method are presented in this paper. Because of the substantial amount of data that has been collected using the loading sleeve, it was considered desirable to compare results from this method with results from the more standard bond wrench method.

Three different mortar mixes were used to construct four sets of six brick unit high masonry prisms for each mortar. The mortars consisted of a control batch, using Type S masonry cement without polymer modification, and two other polymer modified Type S masonry cement mortars with the superplasticizer Rheobuild 1000 added.

For each mortar mix used, two prisms were tested using the loading sleeve device, and the companion two prisms were tested using the bond wrench method. Each test method provided five data values for each prism, or a total of ten data values for each mortar mix tested under each loading device. The flexural tensile bond strength of each mortar joint is given for each test method used.

A comparison of the results is included in an attempt to correlate the loading sleeve test method results to the bond wrench test results. Though the comparison is somewhat inconclusive, the limited test data show that the bond wrench method is more likely to produce less variability in the measured capacities of the mortar joints.

**KEYWORDS: Masonry bond; flexural bond; mortar; brick masonry; bond wrench; tensile bond.**

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## SUMMARY

A modification to the ASTM E 518 flexural bond test has been developed at the University of Maryland using a loading sleeve. The loading sleeve allows the testing in direct flexure of all joints of a masonry prism. The results of a pilot test program to compare the results of flexural bond tests of masonry prisms using the loading sleeve and the bond wrench method are presented in this paper. Though the comparison is somewhat inconclusive, the limited test data show that the bond wrench method is more likely to produce less variability in the measured capacities of the mortar joints.

## INTRODUCTION

The main purpose of the work described herein was to verify the substantial amount of flexural tension strength data obtained on polymer modified masonry mortars by researchers at University of Maryland (Amde et al. 2007; Amde et al. 2006; Colville and Amde 1995; Colville et al. 1999). These researchers used a loading sleeve apparatus which was developed at the University of Maryland. Results obtained using the loading sleeve method are compared, in this paper, to results obtained following the approved ASTM C 1072-94 bond wrench test procedure, Standard Test Method for Measurement of Masonry Flexural Bond Strength (Annual 1997), in order to compare the two test methods and correlate loading sleeve results to results obtained using the bond wrench method. Because of the substantial amount of data that has been collected using the loading sleeve, it was considered desirable to compare results from this method with results from the more standard bond wrench method.

Three different mortar mixes were used to construct four sets of six brick unit high masonry prisms for each mortar. The mortars consisted of a control batch, using Type S masonry cement without polymer modification, and two other polymer modified Type S masonry cement mortars with the superplasticizer Rheobuild 1000 added.

For each mortar mix used, two prisms were tested using the loading sleeve device, and the

companion two prisms were tested using the bond wrench method. Each test method provided five data values for each prism, or a total of ten data values for each mortar mix tested under each loading device. The flexural tensile bond strength of each mortar joint is given for each test method used. A comparison of the results is included in an attempt to correlate the loading sleeve test method results to the bond wrench test results.

## MATERIALS

### Masonry Cement

The scope of the work was limited to a type S masonry cement, obtained in 34 kg (75 pound) bags from the Lehigh Cement Company.

### Sand

The sand was called "play sand" as manufactured by the Sacrete Company. The results of a sieve analysis, following ASTM C 136-96a (Annual 1997) indicated the following cumulative percentages of sand passing, #16 sieve (100%), #30 sieve (94%), #50 sieve (23%), #100 sieve (3%), # 200 sieve (1%), pan (0%). The fineness modulus of 1.80 was within the recommended limits of 1.60 to 2.65.

### Bricks

The bricks used were called Prince William Red Modular 10 hole cored brick as manufactured by the Glen-Gery Corporation, and they complied with the Standard Specification for Building Brick, ASTM C 62-95a, grades SW, MW, and NW (Annual 1997). Measurements of brick size, void area, and initial rate of absorption, modulus of rupture, and compressive strength tests on the brick units were performed in accordance with appropriate ASTM standards.

Average Results were as follows:

| | |
|---|---|
| void area | 21% |
| Initial rate of absorption | 14.3 grams per minute per 19356 sq mm (30 sq in) |
| modulus of rupture | 7178 kPa (1041 psi) |
| compressive strength | 54160 (7855 psi) |

### Chemical Additives

Two latex polymers were used, Rhoplex MC-1834, an acrylic emulsion, manufactured by Rohm and Haas, and Airflex RP-245, a vinyl acetate/ethylene powder, manufactured by Air Products. A liquid defoaming agent, Nopco NXZ, manufactured by Henkel Products, and a naphthalene superplasticizer, Rheobuild 1000, manufactured by Master Builders, were also used in the polymer modified mortar batches. All admixtures were shipped in liquid form, except for the Airflex RP-245, which was shipped in dry form.

## MORTAR BATCH PREPARATION

### Procedures

The same batch preparation procedures were used for each of the three mortar batches used. First the dry components (including the dry form polymer, if used) were measured and added to a mixer and thoroughly mixed. Liquid components were then measured and added to the mixer. Some mixed water was used to rinse all of the liquid components from their containers. Mix water was then added and blended as necessary to provide proper fluidity. After mixing, fluidity, air content, and cone penetration tests were performed on each mortar batch.

### Batch Proportions

For masonry mortars, ASTM C 270-97 (Annual 1997) specifies a sand to masonry cement ratio of 2.25 to 3.00. The ratio used herein was 2.97. Polymers were added based on the ratio of their solid content, at a mass ratio of polymer solids equal to 10% of the mass of the cement in the mortar. The superplasticizer was added at the manufacturer's recommended rate of 1% of the mass of the cement in the batch. The defoamer was added at the manufacturer's recommended rate of 1% of the mass of the polymer solids.

### Water Content

Water/cement (w/c) ratios and flows, measured in accordance with ASTM C 230-90 (Annual 1997), for each of the three batches used were as follows:

| | | |
|---|---|---|
| Type S masonry cement batch | w/c 0.71 | flow 127 |
| Rhoplex MC-1834 batch | w/c 0.52 | flow 84 |
| Airflex RP-245 batch | w/c 0.66 | flow 121 |

## SPECIMEN CONSTRUCTION AND TESTING

### Prisms

All prisms were constructed and cured according to the Standard Specification for Mortar Cement, ASTM C 1329-96 (Annual 1997). Four, six brick unit high, prisms were constructed with each of the three mortar mixes used for a total of twelve prisms. For each mortar batch, two of the prisms were tested using the loading sleeve method developed at the University of Maryland. The companion two prisms for each mortar batch were tested using the ASTM C 1072-94, bond wrench test method.

### Compression Cubes and Cylinders

Three compression cubes and three cylinders were constructed and cured, for each batch of mortar. The cylinders were 101.6 mm by 203.2 mm (4 in by 8 in) in order to be consistent with research done by Brown 1996. With the exception of the cylinder size, the construction of the cubes and cylinders was in accordance with the Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry, ASTM C 780-96 (Annual 1997).

## TEST RESULTS AND DISCUSSION

### Nomenclature

The following codes are used for each of the three batches:

S Type S masonry cement batch without polymer enhancement
SR1834 Type S masonry cement with Rhoplex MC-1834
SR245 Type S masonry cement with Airflex RP-245

### Compression Strength*s*

For each set of three specimens, the coefficients of variation of the cube tests was around 5%, while the coefficient of variation for the cylinder tests was around 2%. Average compressive strengths, in kPa (psi), were as follows.

| mortar batch | cubes | cylinders | cylinders/cubes |
|---|---|---|---|
| S | 7516 (1090) | 6164 (894) | 0.82 |
| SR1834 | 12363 (1793) | 9991 (1449) | 0.81 |
| SR245 | 10018 (1453) | 7584 (1100) | 0.76 |

Loading Sleeve Apparatus

The loading sleeve used in this study is a device that holds each brick prism by clamping the brick on each side of the mortar joint. The assembly is then loaded in third point flexure, The sleeve consists of two identical sections and is constructed of steel plate which is formed into a rectangular box cross section, The two brick units adjacent to the joint that is being loaded rest on a thin plate welded to the inside bottom edge of the loading sleeve, This plate prevents contact between the prism and the base of the loading sleeve during testing, which isolates the other joints from the loading so that they will not be damaged, There are two grooves on each section of the sleeve at the top and bottom of the sleeve to allow for placement of the roller supports used to both apply the load and support the sleeve, The prism is held in place with three screws on each side of the joint being loaded, These screws are screwed down onto a thin one inch plate that rests on the brick units. The moment induced from the applied loading is transferred to the prism through these clamping forces. The sleeve allows the joint to be tested in pure flexure, and no axial force is applied across the loaded joint unlike the bond wrench method. The loading sleeve permits each joint in a prism to be tested and failed separately.

A sketch of the loading sleeve is shown below.

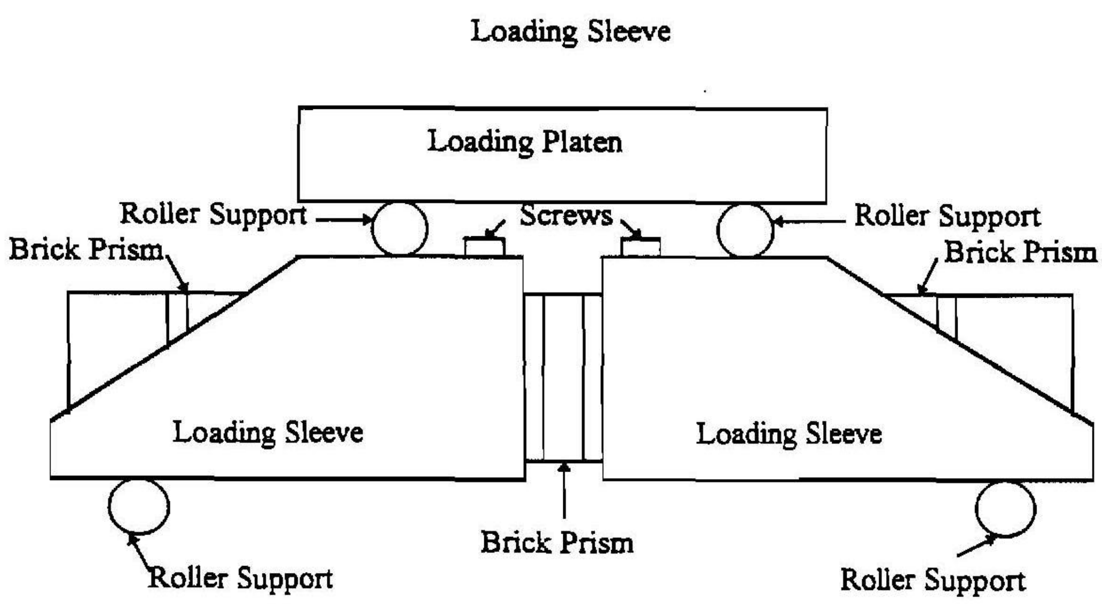


Figure 1. Loading Sleeve

## Flexural Tension Strengths

Detailed information on the loading sleeve apparatus and the method for computing failure stresses using this procedure are given by Brown 1996. However, the load was applied at a rate of approximately 2224 N (500 pounds) per minute until failure occurred. The moment applied to the joint during testing includes the moment due to the applied loading, the moment due to the weight of the loading sleeve itself, and moment due to the specimen weight. Moments due to these three sources can be calculated to determine the moment causing failure and the corresponding modulus of rupture stress. In performing the tests with the loading sleeve it was determined that the method seems to be sensitive to bricks in the prism being horizontally level during testing; especially those bricks against which the loading sleeve is being tightened into position. If either of these units is not well leveled, the result is the introduction of a preload moment that is difficult to assess. A summary of the results for each prism tested, which resulted in five data sets per prism are given in Table 1.

Table 1. Flexural Bond Strengths

| **Batch/ Prism** | **Loading Sleeve Results** | | | **Bond Wrench Results** | | |
|---|---|---|---|---|---|---|
| | Failure Stress kPa (psi) | Std. Dev. kPa (psi) | CoV % | Failure Stress kPa (psi) | Std. Dev. kPa (psi) | CoV % |
| S-1 | 537.8 (78.0) | 94.5 (13.7) | 17.6 | 672.9 (97.6) | 115.1 (16.7) | 17.1 |
| S-2 | 620.5 (90.0) | 239.9 (34.8) | 38.7 | 577.8 (83.6) | 62.7 (9.1) | 10.9 |
| SR1834-1 | 1056.3 (153.2) | 577.1 (83.7) | 54.6 | 974.9 (141.4) | 268.2 (38.9) | 27.5 |
| SR1834-2 | 691.5 (100.3*) | 224.8 (32.6) | 32.6 | 1574.8 (228.4) | 200.6 (29.1) | 12.7 |
| SR245-1 | 1398.3 (202.8) | 175.8 (25.5) | 12.6 | 1031.5 (149.6) | 148.9 (21.6) | 14.4 |
| SR245-2 | 273 (39.6) | 152.4 (22.1) | 55.8 | 321.3 (46.6) | 86.9 (12.6) | 27.0 |

*Average of 4 data set.

From the above results it was noted that the data for prisms SR245-2 were considerably lower than the results from the other sets of specimens. These were the last two prisms constructed in this batch and it is suspected that the mortar which was used to construct these two prisms had begun to set before the mortar was used to construct the prisms. Thus the strengths from both the loading sleeve and the bond wrench tests are considered suspect.

Other observations include the fact that except for prisms S-1, and SR245-1 the variability of the results using the loading sleeve apparatus is considerably greater than that obtained in the bond

wrench testing. While the data for comparison is limited, it would appear reasonable to conclude that the bond wrench is the more reliable of the two test methods.

It is interesting to note also, that for each of the two sets of prisms tested for batches S and SR1834, where at least 9 data sets are available for averaging, the average flexural bond strengths obtained using the bond wrench are higher than those obtained using the loading sleeve. For example for batch S the averages of the prisms are 625 kPa (90.7 psi) for the bond wrench and 579 kPa (84 psi) for the loading sleeve. Corresponding values for SR1834 are 1275 kPa and 894 kPa (184.9 psi and 129.7 psi). This suggests that the loading sleeve apparatus may give conservative results in comparison to the bond wrench method.

Although these findings were reversed for the SR 245-1 batch, it should be noted since batch SR 245-2 is not included in this comparison (since the results are suspect), this reversal is based on only 5 data sets.

## SUMMARY AND CONCLUSIONS

It had been hoped that the comparison of results from the two test methods would have been more consistent than was found. These preliminary comparisons show that the bond wrench method is more likely to produce less variability in the measured capacities of the mortar joints. However, it is also felt that if adequate care is taken in conducting tests using the loading sleeve device, conservative, yet reasonable estimates of flexural tension bond strength of mortared joints can be obtained, as evidenced by some of the test data. It is also clear, however, that to verify these observations, and more accurately and reliably correlate the results from the loading sleeve method to the accepted bond wrench method, more testing is needed.

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