International Building Lime Symposium 2005
Orlando, Florida, March 9 -11, 2005

DEVELOPMENT OF A STANDARDIZED LABORATORY APPARATUS FOR MEASURING EMLEY BASEPLATE RATE OF ABSORPTION*

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Abstract

ASTM C 110-04, Standard Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone, mandates requirements for the rate of absorption of Emley Plasticimeter baseplates. However, beyond a short, non-mandatory note, the current test method does not provide guidance for constructing an apparatus to measure baseplate rate of absorption. This paper outlines the construction and use of such an apparatus.

Keywords

Emley Plasticity, Baseplate Rate of Absorption

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1 Introduction

ASTM C 110-04 (C110), Standard Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone, outlines the test method for determining the plasticity of lime putty (ASTM 2004). Plasticity is a physical measurement of the degree of stiffening of lime putty as water is withdrawn by an absorptive surface. This property is important for mixtures containing lime in operations such as plastering, stuccoing, and masonry construction.

The test method involves mixing a lime putty to standard consistency, molding the putty onto an absorptive baseplate and testing the plasticity of the putty using an Emley Plasticimeter. The absorptive baseplate may be made of plaster or porcelain, as long as the plate meets water-testing requirements for both total and rate of absorption. In an earlier paper, the authors established a need for “continued development of clearly-defined procedures, apparatus, materials and measurement of baseplate rate of absorption” (Godbey and Thomson, 2002). The main goal of this paper is to evaluate an apparatus that was developed to measure the rate of water absorption of Emley baseplates.

2 Background

Baseplate rate-of-absorption requirements are mandated in ASTM C 110 (Table 1).

Table 1. ASTM C 110 Baseplate Rate-of-Absorption Requirements.

Time, minutes	**Water Absorbed (mL)**	
	Minimum	**Maximum**
1	8	14
2	5	7 1/2
3	4	6 1/2
4	4	6
5	3 1/2	5 1/2

Guidance on performing the rate-of-absorption test is outlined in non-mandatory ASTM C 110 Note 4: “A convenient apparatus for determining the rate of absorption consists of a buret sealed onto an inverted glass funnel from which the stem has been removed. The diameter of the larger end of the funnel shall be ground so as to be 70 mm (2 ¾ in.) in internal diameter. The funnel may be attached to the plate on which the measurement is being made by melted paraffin. The paraffin should not be too hot. A little experience will indicate when it is of the proper consistency.” (ASTM, 2004) Using this guidance, the authors began experimenting with the absorption apparatus, but had limited success using the suggested materials. The modified glass funnel attached to a buret tended to entrap air at the funnel-buret transition zone, and the melted wax method of funnel-to-plate attachment was problematic in achieving a watertight seal.

After this initial effort, the authors’ next iteration of the apparatus used a polycarbonate Erlenmeyer flask that was modified into a funnel and attached to a buret using a cored rubber stopper. Entrapped air at the rubber stopper transition zone was a problem, but a few brisk taps of the polycarbonate funnel, just after filling the apparatus with water, allowed the bubbles free passage up and out of the system. However, trials with the melted wax method of attachment did not improve the watertight seal. Through experimentation with various other sealants, the authors discovered that using a two-part epoxy to seal the polycarbonate funnel to the baseplate worked very well and allowed reuse of the polycarbonate funnel during additional trials (Figure 1). However, after testing, removal of the

Figure 1. Author's early absorption apparatus using 2-part epoxy to attach the modified funnel to the baseplate. (ASTM STP 1432, Masonry: Opportunities for the 21st Century, 2002)

funnel from the baseplate destroyed the baseplate testing surface, precluding reuse of the plate. Epoxy mixing, epoxy curing time and funnel clean-off after testing also took too much extra time.

During these first efforts, the authors became aware of a laboratory that had taken a different view of the work. This laboratory had developed an absorption apparatus that used a reservoir system hooked up to a buret and a lever-arm clamping system to achieve a watertight testing seal between the testing diameter and the baseplate. In this system, water is introduced to the <u>bottom</u> of the plate against the force of gravity. In many ways, this system appeared to be superior to the authors' efforts because of the potential to reuse the baseplate after absorption testing. The lever arm clamping system purportedly did not destroy the testing surface of the plate as did the authors' epoxy method. Notwithstanding questions about the effect of wetting and drying on a plaster base plate, the authors decided to design an improved apparatus with an alternative method of achieving a watertight seal, while maintaining the spirit of the original guidance of gravity head <u>top down</u> testing as loosely outlined in ASTM C 110 Note 4.

3 Design, fabrication, and use of the improved Emley absorption apparatus

The authors' third generation apparatus for measuring Emley baseplate rate of water absorption was fabricated using a combination of precisely-machined thrust plates, precision-cut neoprene cushion and seal, and partially-machined PVC ball valve, as well as other commonly-available laboratory and hardware items. The apparatus has two parts; a lower thrust portion and an upper filling portion. The two parts are connected during calibration and use, but separated for transport, storage, emptying, and clean-up after use. Total height of the assembled apparatus is 121.92 cm (4 ft.). The footprint diameter of the assembled apparatus is 25.4 cm (10 in.). Dry weight of the lower assembled apparatus, including an Emley baseplate, is 10.7 kg (23.6 lbs.) and dry weight of the upper assembled apparatus is 0.23 kg (1/2 lb.). The apparatus is shown in Figure 2.

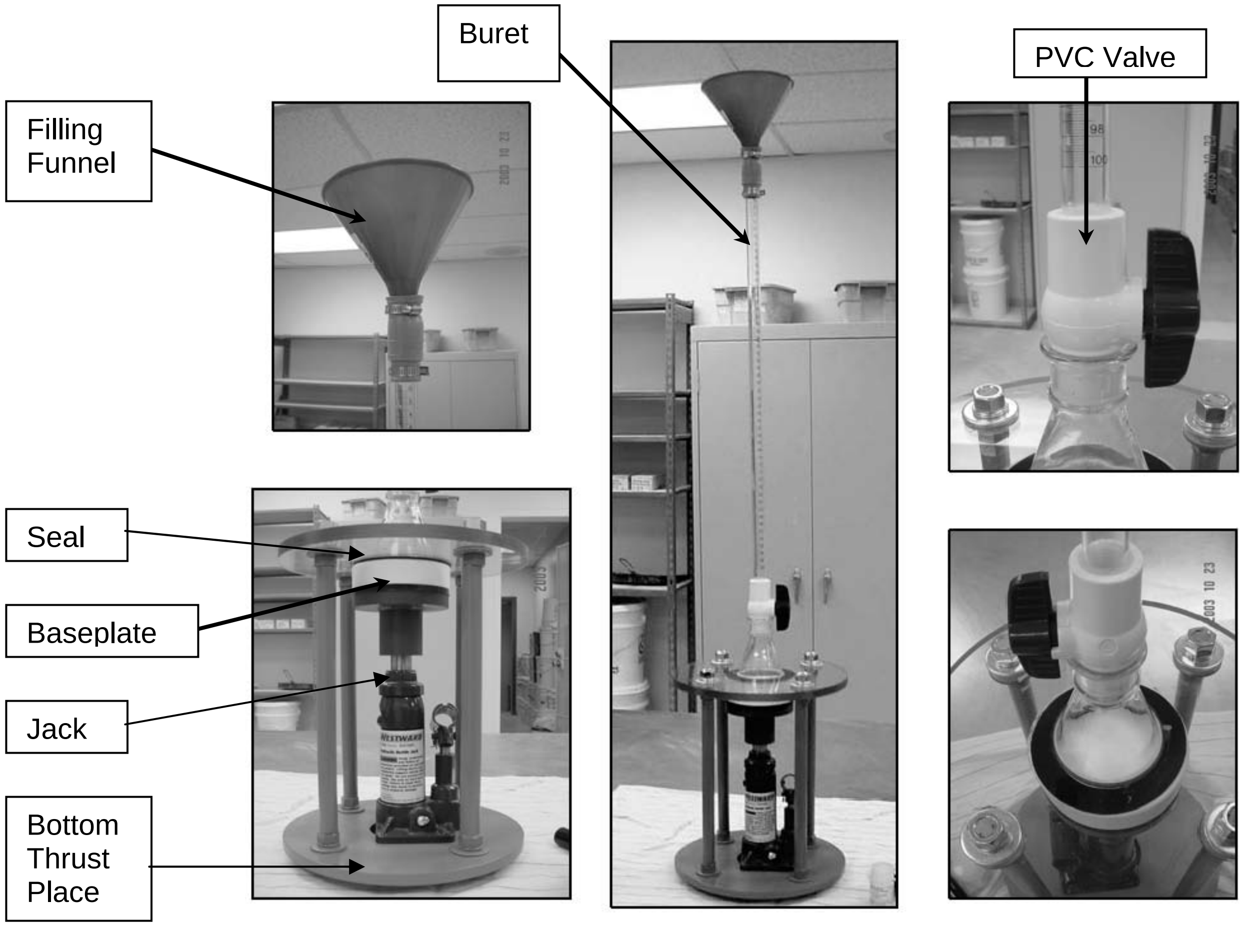

Figure 2. Emley rate of absorption apparatus showing several different views of design and component parts

The lower thrust portion of the apparatus utilizes a 1.81 mton (2-ton) Westward Model 3ZC58G hydraulic bottle jack captured between two thrust plates that are 25.4 cm (10 in.) in diameter to supply linear thrust clamping pressure to an Emley baseplate. The upper thrust plate disk is machined from clear 1.27 cm (1/2 in.) thick polycarbonate stock. This upper plate has the 70 mm (2.75 in.) testing diameter precisely machined into the center of the thrust disk. The bottom thrust plate is machined from 1.27 cm (1/2 in.) thick steel plate. The apparatus thrust plates are supported and held apart by 1.27 cm (1/2 in.) diameter coarse-threaded steel rod that is sheathed by ordinary 1.27 cm (1/2 in.) galvanized EMT (electrical) conduit for aesthetics and handling safety. The threaded rod is connected to each side of each thrust plate by thrust washers, lockwashers, and coarse-threaded nuts. The bottom surface of the baseplate is cushioned by a 6.24 mm (1/4 in.) thick, donut-cut, 10.16 cm (4 in.) diameter, neoprene gasket in contact with the 10.16 cm (4 in.) diameter hydraulic jack cap. The jack cap is fabricated from 1.27 cm (1/2 in.) thick steel plate with a nominal 2.54 cm (1 in.) inside-diameter welded nipple that fits over the ram arm of hydraulic jack. Thrust force is directed through the jack cap, donut cushion and baseplate to form a watertight seal between the upper testing surface of the baseplate and the apparatus absorption testing diameter by the use of a precisely-cut, 1.06 mm (1/24 in.) thick, donut-cut, neoprene gasket. The inner diameter of this donut-cut gasket is 71.82 mm

(2.82 in.), or 1.82 mm (1/14 in.) larger than the testing diameter (70 mm; 2.75 in.). The overall outer diameter of this gasket is 10.16 cm (4 in.) This allows the seal to deform under compression to exactly the same inside diameter as the testing diameter. Using a hacksaw, the modified funnel is cut from the upper portion of a polycarbonate Erlenmeyer flask and manually ground down on a disk sander to a slightly larger diameter than the testing diameter. It forms an intimate contact and slight friction-fit into the upper portion of the testing diameter that was machined into the upper polycarbonate thrust plate. This friction-fit allows the funnel filler neck to be made plane to the surface of the thrust plate. (The testing diameter is established by precision machining of the thrust plate, not the modified funnel itself.) The watertight seal between the funnel and the thrust plate is made by the use of a polycarbonate plastic welding solvent or two-part epoxy. Metal parts of the apparatus are spray painted for aesthetics and corrosion resistance.

The upper portion of the apparatus is a combination of a 1.27 cm (1/2 in.) PVC ball valve, 100mL acrylic buret barrel and a plastic funnel. The PVC valve-buret-funnel assembly makes a removable connection to the lower portion of the apparatus. The lower portion of the PVC ball valve is precisely machined to make a slight friction-fit into the upper filler neck of the modified Erlenmeyer flask funnel.

This removable connection allows the apparatus to be broken down for transport and emptying of excess water after testing. This connection is lubricated and made watertight by the use of ordinary laboratory-grade vacuum grease. The upper portion of the PVC ball valve accepts the lower portion of the acrylic buret barrel without modification. This connection is made by slipping the buret into the upper threaded portion of the internal diameter of the ball valve until the buret bottoms against the valve's main body. This connection is welded together with plastic solvent, or otherwise made watertight with two-part epoxy. The upper portion of the buret barrel is mated with the plastic filler funnel by using an ordinary flexible rubber dishwasher pipe connector. The dishwasher pipe connector is slipped over the buret barrel and the connector hose clamp is tightened just enough to effect a watertight seal. The outlet of the plastic funnel is inserted into the larger diameter of the dishwasher pipe connector until it makes intimate contact with the upper portion of the buret, and then the upper hose clamp is tightened just enough to make a watertight seal. Because the plastic funnel outlet has a slight taper to it, the outside surface of the outlet may be roughened with sandpaper prior to clamping to help prevent slippage. The entire (valve-buret-funnel) upper portion of the apparatus is left assembled for ease of testing, but the upper plastic funnel may be removed for shipping and reassembled for use.

Use of the apparatus starts by verifying the water-tight condition of all joints and seals and ensuring the pre-fill volume of the modified funnel to the 100 mL index mark on the buret. The volume of water in the final fill is precisely tracked using a 250 mL graduated cylinder. The ball valve is opened and a digital timer is manually started simultaneously. Visual measurements and manual recording of the volume of water absorbed is performed at 1-minute intervals for a period of 5 minutes. Using the known total starting volume of water added to the apparatus, the volume of the apparatus' modified funnel and the 1-minute interval measurements, the absorption rate can be calculated by a specially-designed spreadsheet that back-calculates the rate of absorption over each 1-minute time interval.

4 Comments, suggestions, and testing results

Three identical prototype apparatus were built (Figure 2), shipped, and tested by three different laboratories. For the initial series of tests, plaster baseplates were donated by a commercial baseplate manufacturer. The plates were shipped directly from the manufacturer to the authors' laboratory, individually identified, weighed and assigned random numbers for re-shipment to the individual testing laboratories. Each lab received five baseplates to begin their evaluation. The individual laboratories followed the same written protocol and were charged with generating comments about the use of the apparatus. Additionally, each laboratory was asked to test each one of their randomly-assigned plates a total of three times. Plates were oven-dried at 43°C (110 °F) prior to each test. (NOTE: Never dry plaster baseplates at elevated temperatures approaching or exceeding the boiling point of water because cracking and destruction of the plate will occur).

In general, comments regarding use of the apparatus were positive. One laboratory commented, "*The apparatus worked great right out of the box. It was simple to operate…I am encouraged and enthusiastic with just one afternoon of getting friendly with the apparatus*." Another laboratory commented, "*Easy to work with*." In general, the overall suggestive comments addressed concerns with the height and weight of the apparatus, entrapment of air bubbles on the wall of the modified funnel, air rising during the start of the test and "gurgling" water out the top of the apparatus, and the development of pinholes on the testing surface of the baseplate where the baseplate made contact with the upper thrust plate and the neoprene gasket.

The authors control the gurgling water issue by placing a loosely-fitted 1-gallon metal paint can lid over the top of the plastic filling funnel during testing. The lid acts as a splashguard to keep all water in the apparatus during the test. To remove air bubbles from the system, the authors use light taps with the jack handle around the perimeter of the modified funnel as the modified funnel is filled when the PVC ball valve is opened. This bubble-removing operation is accomplished within the first 30 seconds of testing. Although minor air bubbles can be visible in the system, a low standard deviation in the testing data shows that the presence of this level of air is not significant to the test. For apparatus users of shorter stature, the authors recommend setting the apparatus on a low table or the floor during testing.

One lab suggested that the weight of the apparatus could be reduced by machining the bottom thrust plate out of aluminium instead of steel. This lab also suggested that the bottle jack should fit into a three-sided slot for added stability and ease of alignment. Plate pinholes are avoided by reducing clamping pressure and were more evident with repeated testing of the same plate and earlier commercial plate mix designs. The amount of force needed to obtain a watertight seal between the baseplate and the upper thrust plate/testing diameter is well below the capacity of the jack and is only as much as is needed to compress the upper neoprene seal (about a quarter pump of the jack handle after the plate is jacked into contact with the seal). Excessive pressure is evident by looking at the seal and determining its level of compression. Excessive crushing and flattening of the seal should be avoided; proper compression is evident when the seal shows only a very slight decrease in thickness and a very slight bulging of its sides.

Apparatus comments aside, there were two very important results of this initial series of round robin testing: the manufactured plates that were first tested in the round robin did not meet the absorption requirements; and the plates could not be reused (Table 2 and Figure 3). In response to the failed absorption requirements, the manufacturer adjusted the plaster mix design, made a fresh batch of plates and sent the second series of plates out for testing. Disappointingly, this second set of plates did not meet the absorption requirements either (Table 3 and Figure 4). With the second failure, the manufacturer made additional refinements to the plaster mix design with tighter controls on the mixing water temperature and better precision in the gravimetric batching of materials. This resulted in a successful, third set of plates in which each plate met the absorption requirements (Table 4 and Figure 5).

Table 2. Commercial Plate Plaster Mix Design (Series #1) Rate of Absorption Results.

Time (minutes)	Average Water Absorbed 15 Plates mL/minute (Std. Dev)		
	Test 1	**Test 2**	**Test 3**
1	17.0 (0.6)	21.2 (2.8)	26.3 (2.1)
2	8.9 (0.3)	12.6 (0.9)	13.1 (0.9)
3	7.8 (0.1)	10.1 (0.7)	9.6 (0.5)
4	6.7 (0.1)	7.9 (0.1)	6.6 (0.5)
5	5.9 (0.1)	4.6 (1.1)	2.2 (1.1)

Table 3. Commercial Plate Modified Plaster Mix Design (Series #2) Rate of Absorption Results.

Time (minutes)	Water Absorbed (mL/minute) Average of 9 Plates	Standard Deviation
1	17.0	0.6
2	8.9	0.3
3	7.8	0.1
4	6.7	0.1
5	5.9	0.1

Table 4. Commercial Plate Modified Plaster Mix Design (Series #3) Rate of Absorption Results.

Time (minutes)	Water Absorbed (mL/minute) Average of 9 Plates	Standard Deviation
1	11.7	0.6
2	6.7	0.4
3	5.7	0.6
4	5.0	0.5
5	4.7	0.2

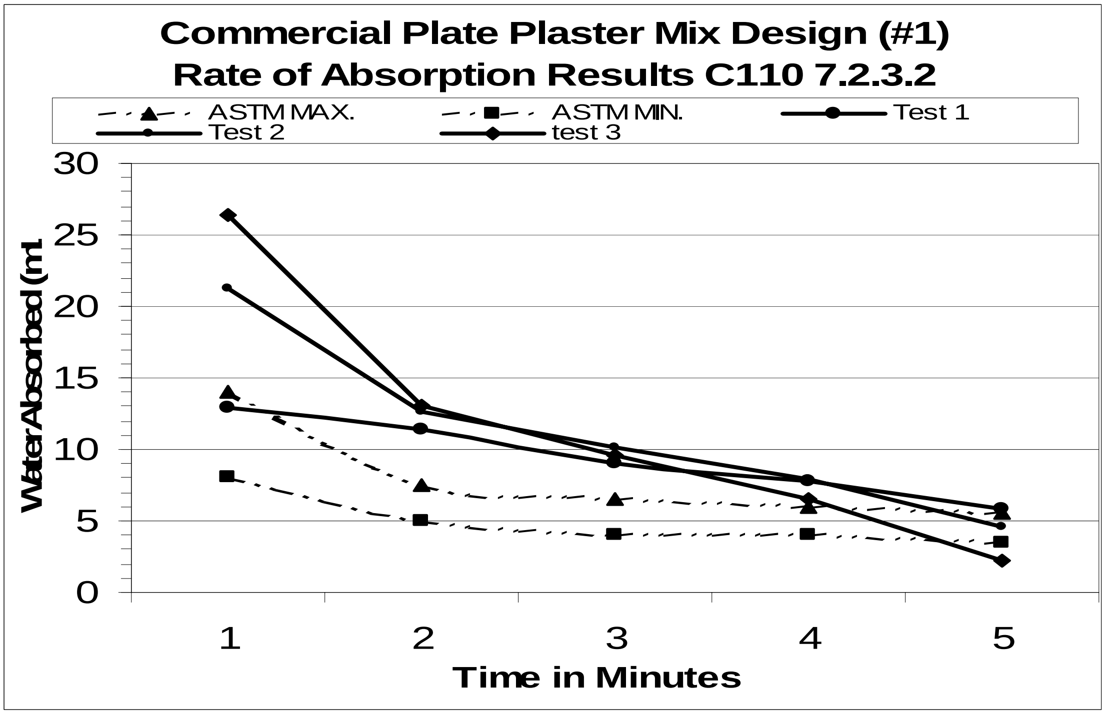

Figure 3. Commercial Plate Modified Plaster Mix Design (Series #1) Rate of Absorption Results.

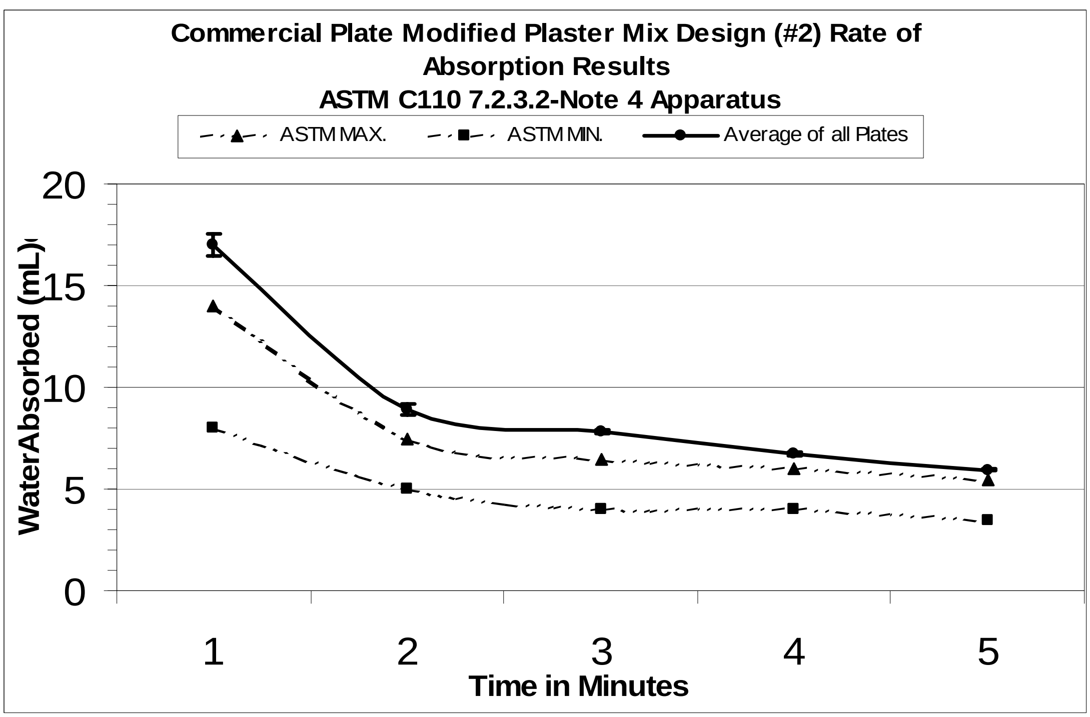

Figure 4. Commercial Plate Modified Plaster Mix Design (Series #2) Rate of Absorption Results.

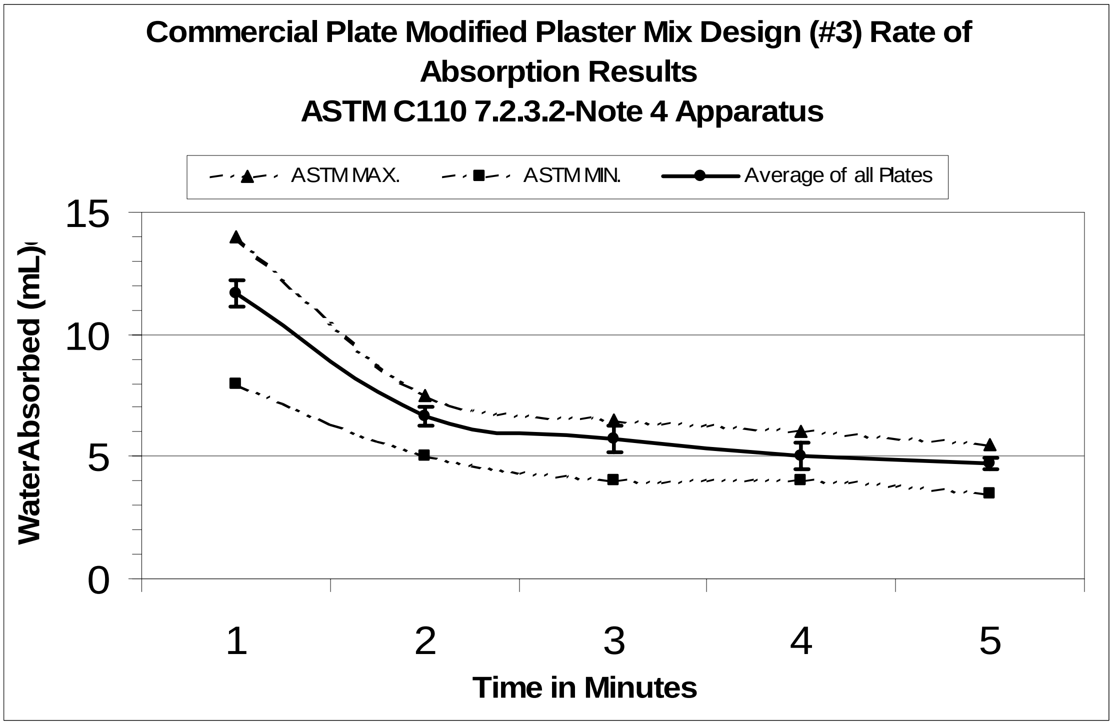

Figure 5. Commercial Plate Modified Plaster Mix Design (Series #3) Rate of Absorption Results.

Part of the reason for developing an apparatus with a clamping system was the potential to reuse baseplates for plasticity testing after performing the rate-of-absorption testing. While the authors always maintained that this might be problematic, this series of round robin testing confirmed that the matrix of the baseplate is changed after just one series of wetting and drying (Figure 6). As the figure shows, the matrix of the plaster baseplate opens up with each repeated cycle of drying and wetting. The end effect is a more rapid rate of absorption in the first two minutes and, as the matrix becomes saturated during the duration of the test, a slower rate of absorption in the final two minutes. As such, plaster baseplates cannot be tested with water, dried, and reused in plasticity testing. The ramification of this knowledge is that an individual batch of plaster baseplates must be characterized in terms of rate of absorption through statistical analysis. Additional testing and analysis will have to be conducted to establish the number of plates that must be tested per batch to meet the requirements of a statistical characterization. Experimental error associated with the apparatus and test method needs to be better characterized, as well.

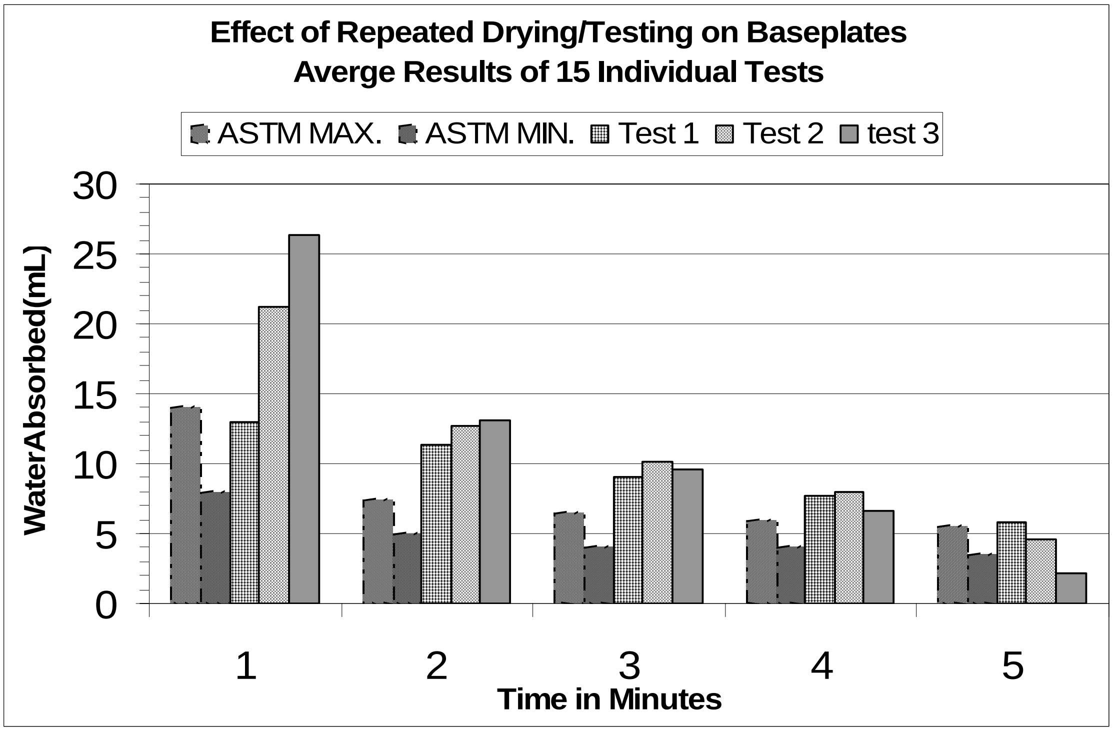

Figure 6. Effect of Repeated Drying/Testing Cycles on Baseplate Rate of Absorption.

5 Conclusion

Emley baseplate rate-of-absorption testing is a critical element of Emley plasticity testing. To ensure that baseplates meet the rate-of-absorption requirements outlined in ASTM C 110, rate-of-absorption testing must be conducted using an absorption apparatus. According to users, the apparatus presented in this paper is easy to use; however, it is tall and heavy. A lower testing table and lighter fabrication materials may improve the ease of use of this apparatus. Nevertheless, the as-designed and tested apparatus meets the principle of top down testing with a falling head pressure, utilizing a buret and modified funnel as indicated in C 110 Note 4.

Round robin testing performed during the evaluation of this apparatus showed that commercially-available plates did not meet the absorption requirements of ASTM C 110. Manufacturer-initiated adjustments to the mix design, mixing water temperature and gravimetric material measurements improved the plates so that they do meet the absorption requirements.

Plaster baseplates are sensitive to repeated wetting and drying. Because this repeated wetting and drying changes the absorption character of an individual plate, the plate cannot be used for Emley Plasticity testing after absorption testing.

Acknowledgements

The authors wish to acknowledge Chemical Lime Company, a Lhoist Group Company, for its continued support of Emley Plasticity testing.   Additionally, the authors would like to thank Geotest Instruments Corp. (IL), Graymont Dolime Inc. (OH), and Western Lime Corp (WI) for their assistance in this evaluation of the rate-of-absorption apparatus. Without their comments, work, and cooperation, this study would not have been possible.

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