Effect of Containers on ASTM C441—Pyrex Mortar Bar Expansions

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ABSTRACT

From preliminary tests and participation in a recent ASTM interlaboratory program, it was found that the container type, and especially distance of the mortar bars from the wicking, had a large effect on resultant expansions of ASTM C 441 Pyrex mortar bars. Recently, a larger evaluation program of ten different containers and wicking arrangements was initiated. After 84 days at 38°C and 100% rh, mortar bar expansions had levelled off and were found to vary from 0.179% to 0.471% with the proposed new ASTM standard container giving 0.446%.

The results indicate that present attempts by ASTM to specify a standard container are important but some alternate containers are still suitable for use if they provide equivalent expansions to those of the standard. Alkali leaching did not appear to reduce expansions in the containers.

INTRODUCTION

The ASTM C 227 Test Procedure for expansion of mortar bars was originally adopted in 1950 although it retained a tentative designation until 1964. Prior to the 1960 revision photos and sketches were shown of the required containers which only had to be metal and could contain up to 36 bars.

The requirements for the storage container in 1960 revision (1) were that moisture loss be prevented by tight-fitting covers or by sealing or by both, and that the vertically stored bars should not touch the sides of the container nor be subject to water splashing from the reservoir or condensation dripping from the lid. Wicking, to ensure a high relative humidity throughout the container, was not required.

The 1969 revision (2) was the first to require the inner surfaces of the container to be lined with an absorbent material, such as blotting paper, to act as a wick. These requirements are basically the same as those in the 1985 Book of ASTM Standards (3). However, changes to the container requirements are imminent.

Irrespective of the specified requirements, the purpose of the containers, and later the wicking, was to try and provide a sealed 100% rh environment in order to maximize the rate of expansion of alkali reactive aggregates.

PRELIMINARY TESTS

Recently, the ASTM C09.02.02 committee on Chemical Reactions in Concrete found, through a series of interlaboratory testing using standard ASTM C 441 Pyrex glass and a high alkali portland cement, that a wide range of expansions were obtained when different containers were used (4). The three-month expansions in ten different containers, all of which complied with either pre-1969 or existing requirements and containing either 4, 6, 8, 16, 24 or 50 mortar bars, ranged from 0.366 to 0.584% (coefficient of variation = 17.4%).

The range of three-month expansions was narrowed to between 0.424 and 0.564% (seven laboratories, coefficient of variation = 10.4%) when a new, six bar container having inner and outer concentric wicks was tested. A cross-section of the new container (which is obtaining final approval for adoption as a reference container in ASTM C 227), is shown in Figure 1. (The new C 227 requirements will allow use of other containers as long as they provide equivalent expansions).

While participating in the ASTM interlaboratory test program, the author initiated a supplementary program to evaluate the effect of the average distance between the mortar bars and the wicking on expansion. Holes were drilled in a plexiglas plate to space the mortar bars in a 22 litre plastic pail so that their centres were either 44, 64 or 95 mm from the wicks. Both ASTM C 441(5) Pyrex and standard Ottawa sand mortar bars were cast using a high-alkali cement (Na_2O eq = 0.90%). The expansions are plotted along with those for the new ASTM container as a function of wick spacing in Figure 2. While the wicking distance had no effect on the non-reactive Ottawa sand, a significant trend was observed with reactive Pyrex glass. While Pyrex typically expands quickly and the expansion is essentially complete after only three months, the mortar bars in the 22 litre pail were monitored for 12 months. These bars were then placed in the new ASTM containers and stored for a further six months to see whether some of the "lost" expansion could be recovered. However as shown in Table 1, almost no further expansion was observed. This effect may be specific to Pyrex and may not apply to natural aggregates.

Evaluation of Alternate Containers

Due to the imminent adoption of the new container design by ASTM (subject to final balloting), it was decided to evaluate the expansions obtained in containers used by Ontario Hydro and other Canadian research laboratories relative to the new container. Again, for simplicity Pyrex glass, prepared as described in ASTM C 441, and a high-alkali portland cement (Na_2O eq = 1.17%) were used. In addition to the new ASTM container (Figure 1), tests were conducted on Ontario Hydro's old, unwicked 4 bar container (used prior to 1969) and a modified two bar version (Figure 3), a commercially available photographic developing tank (Figure 4), a widely used 25 bar box

(Figure 5), an 18 bar rectangular container (Figure 6), a 4 bar, un-wicked 22 litre pail[1] (Figure 7) and a new Ontario Hydro designed 12 bar, 22 litre pail with some of the bars oriented so all four faces were equidistant from the wicks and some bars having two opposite faces flat to the wicks (Figure 8). In addition, four of the bars in the 18 bar container (Figure 6) were sealed in individual vinyl sleeves containing 5 to 10 mL of water. The idea of the vinyl sleeves (8) was to prevent potential loss in expansion due to alkali-leaching into the reservoirs of storage containers. Dummy bars were used to fill every space in each container in order to simulate a full loading.

RESULTS

The expansion of the Pyrex mortar bars in the nine different containers are plotted up to 84 days in Figure 9. It can be observed that several of the containers gave rates and total expansions essentially the same as that for the new ASTM container, but several of the containers gave results which were significantly different as shown in Table 2.

Very low expansions were obtained for the two containers not having wicks and for the bars sealed in individual vinyl tubes. The vinyl tubes had been found elsewhere (6) to result in an increased rate of expansion when used with natural reactive aggregates, so this result was somewhat surprising. The low expansions obtained here may be related to the rapid reactivity of Pyrex glass combined with the small amount of water placed inside the vinyl sleeves. Further work is being undertaken using a natural reactive aggregate.

As stated earlier, one the of the reasons for adoption of the vinyl sleeves was to eliminate alkali leaching effects. However, from chemical analysis of the water in the reservoirs of each container after 56 days, it was found that increased alkali leaching did not result in decreased expansions. In fact, all the containers giving high expansions equivalent to that of the new ASTM container, exhibited the highest alkali leaching as shown in Table 3. Perhaps the concentration of alkali in the relatively small reservoirs is insignificant with respect to the total alkalis in the bars and it actually may indicate the efficiency of the container in maintaining near 100% rh conditions.

Effect of Orientation of Bars

In the experimental 12 bar, 22 litre pail shown in Figure 8, 4 mortar bars were oriented so all 4 faces of the bars were equidistant from the wicks (to better simulate conditions in the new ASTM container) and 4 were oriented so only two faces were parallel to the inner and outer wicks. The average 84 day expansion for the former was 0.419% and 0.455% for the latter. By the Student's T test, the two sets of expansions were found to be significantly different at the 10% level. Therefore, for this container, positioning the bars so that two faces are closer to the wicks appears to be preferable.

SUMMARY AND CONCLUSIONS

1. There are containers that can provide equivalent expansions to the new ASTM C 227/C 441 reference container.

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1. This container arrangement (6) has been abandoned by Laval University in favour of a more satisfactory container similar to the new Hydro 12 bar wicked pail (7).

2. A 22 litre (5 gallon) plastic pail fitted with inner and outer concentric wicks and with 12 equally spaced mortar bars appears to provide equivalent expansions and is inexpensive to construct.

3. Some containers used by Canadian researchers and specifying agencies do not give expansions equivalent to the new ASTM container.

4. With Pyrex, if low expansions result due to use of a poor container, the difference in expansion can not by recovered by changing containers at a later age.

5. Sealing bars in individual vinyl bags may have merit with natural aggregates but expansions with quick-expanding Pyrex are greatly reduced. It is intended to conduct further research in this regard.

6. In spite of concerns by researchers with alkali leaching of the mortar bars, higher concentrations of alkalis in the water reservoirs were found to be related to higher expansions. Therefore, leaching may not be as critical as is generally thought.

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7. Bérubé, M.A., 1986. Personal Communication, Laval University, August 14.

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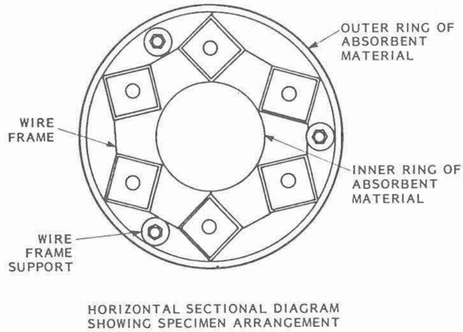

FIGURE 1 - New ASTM 6-Bar Container

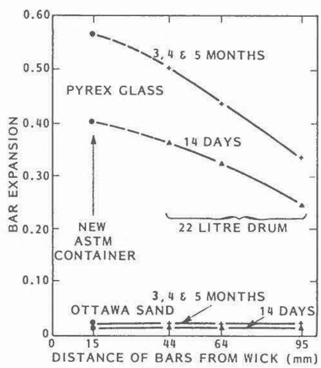

FIGURE 2 - Effect of Wick Distance on Expansion of ASTM C 227 Mortar Bars

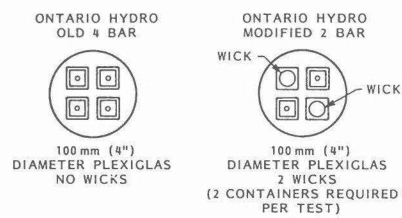

FIGURE 3 - Old Ontario Hydro Unwicked Container and Modification

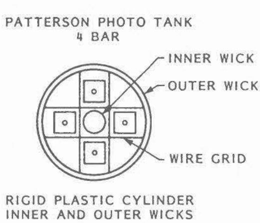

FIGURE 4 - Four Bar Photo Tank Containers

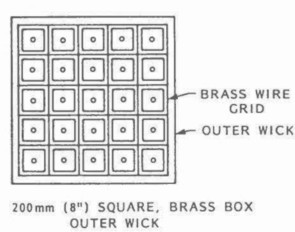

Figure 5 - Metal 25 Bar Container

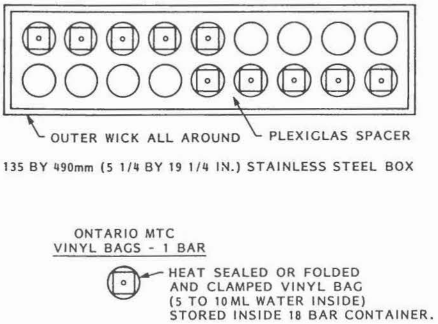

FIGURE 6 - Stainless Steel 18 Bar Container and Vinyl Bags

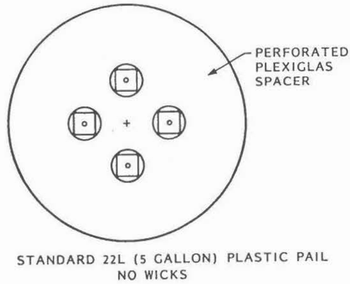

FIGURE 7 - 22 Litre, 4 Bar Unwicked Container

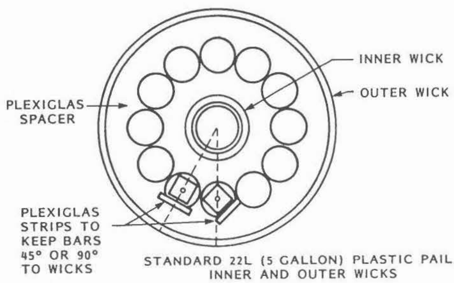

FIGURE 8 - Ontario Hydro Modified 12 Bar Container

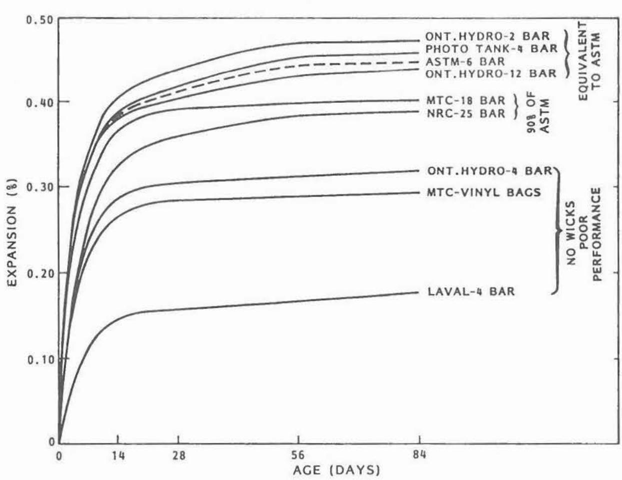

FIGURE 9 - Effect of Container on ASTM C 441 Pyrex Mortar Bar Expansions

• BARS WERE TAKEN FROM THE EXPERIMENTAL 22 LITRE PAIL AFTER 12 MONTHS AND PLACED IN THE NEW ASTM CONTAINER UNTIL 18 MONTHS.

ORIGINAL CONTAINER TYPE	12 MONTH EXPANSION (%)	EXPANSION IN ASTM CONTAINER AT 18 MONTHS (%)
ASTM - 6 BAR	.566	---
EXPERIMENTAL PAIL		
44mm POSITION	.340	.344
64mm POSITION	.359	.373
95mm POSITION	.384	.393

TABLE 1
Effect on Pyrex Mortar Bar Expansions of Changing to a Higher Humidity Container

CONTAINER	AVERAGE EXPANSION (%)	COEFFICIENT OF VARIATION (%)	NO.OF BARS IN TEST	SIGNIFICANTLY DIFFERENT FROM ASTM CONTAINER?	LEVEL OF SIGNIFICANCE
ASTM - 6 BAR	.446	5.2	6	--	--
ONT.HYDRO-2 BAR	.471	6.6	4	NO	10%
PHOTO TANK-4 BAR	.458	2.9	4	NO	10%
ONT.HYDRO-12 BAR	.437*	7.5*	8	NO	10%
MTC-18 BAR	.400	6.5	10	YES	1%
NRC-25 BAR	.390	7.7	8	YES	1%
ONT.HYDRO-4 BAR	.317	1.9	4	YES	1%
MTC-VINYL BAGS	.295	6.9	4	YES	1%
LAVAL-4 BAR	.179	9.2	4	YES	1%

* INCLUDES BARS WITH BOTH FLAT FACES AND CORNERS TO WICKING

TABLE 2
Statistical Analysis of 84 Day ASTM C 441 Mortar Bar Expansions (Students T Test)

CONTAINER	pH	[Na+] mg/l	[K+] mg/l	56-DAY EXPANSION %
ASTM - 6 BAR	12.1	3,940	7,980	0.442
ONT HYDRO-2 BAR	11.5*	1,470*	2,730*	0.466*
PHOTO TANK-4 BAR	12.3	3,990	10,100	0.453
ONT HYDRO-12 BAR	10.3	1,360	3,150	0.428
MTC-18 BAR	11.5	1,420	2,460	0.397
NRC-25 BAR	11.0	685	1,150	0.383
ONT HYDRO-4BAR	11.1	500	1,755	0.309
MTC-VINYL BAGS	-	-	-	0.290
LAVAL-4 BAR	9.5	165	3	0.166

* AVERAGE FROM 2 CONTAINERS

TABLE 3
Analyses of Water in Reservoirs of Containers After 56 Days