U. S. DEPARTMENT OF COMMERCE

# BUILDING MATERIALS AND STRUCTURES

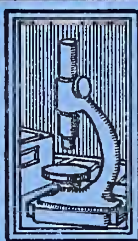
REPORT BMS55

## Effects of Wetting and Drying on the Permeability of Masonry Walls



*by*

CYRUS C. FISHBURN



NATIONAL BUREAU OF STANDARDS

The program of research on building materials and structures, carried on by the National Bureau of Standards, was undertaken with the assistance of the Central Housing Committee, an informal organization of governmental agencies concerned with housing construction and finance, which is cooperating in the investigations through a committee of principal technicians.

## CENTRAL HOUSING COMMITTEE ON RESEARCH, DESIGN, AND CONSTRUCTION

A. C. Shire, *Chairman.*
United States Housing Authority.

Howard P. Vermilya, *Vice Chairman.*
Federal Housing Administration.

Sterling R. March, *Secretary.*

Pierre Blouke,
Federal Home Loan Bank Board.

Hugh L. Dryden,
National Bureau of Standards.

Louis A. Simon,
Public Buildings Administration.

Luther M. Leisenring,
Construction Division (War).

Edward A. Poynton,
Office of Indian Affairs.

John S. Donovan,
Farm Security Administration.

George W. Trayer,
Forest Service (F. P. Laboratory).

Joseph M. DallaValle,
Public Health Service.

George E. Knox,
Yards and Docks (Navy).

William R. Talbott,
Veterans' Administration.

Wallace Ashby,
Bureau of Agricultural Chemistry and Engineering.

---

## NATIONAL BUREAU OF STANDARDS STAFF COMMITTEE ON ADMINISTRATION AND COORDINATION

Hugh L. Dryden, *Chairman.*
Mechanics and Sound.

Phaon H. Bates,
Clay and Silicate Products.

Hobart C. Dickinson,
Heat and Power.

Warren E. Emley,
Organic and Fibrous Materials.

Gustav E. F. Lundell,
Chemistry.

Addams S. McAllister,
Codes and Specifications.

Henry S. Rawdon,
Metallurgy.

The Forest Products Laboratory of the Forest Service is cooperating with both committees on investigations of wood constructions.

[For list of BMS publications and directions for purchasing, see cover page III]

UNITED STATES DEPARTMENT OF COMMERCE · Harry L. Hopkins, Secretary

NATIONAL BUREAU OF STANDARDS · Lyman J. Briggs, Director

# BUILDING MATERIALS *and* STRUCTURES

## REPORT BMS55

## Effects of Wetting and Drying on the Permeability of Masonry Walls

*by* CYRUS C. FISHBURN

ISSUED SEPTEMBER 18, 1940

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

UNITED STATES GOVERNMENT PRINTING OFFICE · WASHINGTON · 1940

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C. · PRICE 10 CENTS

# Foreword

This paper gives the results of further studies of the resistance of masonry walls to penetration by dampness when exposed to wind-driven rain. The exposure of masonry walls to wind-driven rains, with subsequent drying, produces changes in moisture content of the walls. Since the volume changes produced by the wetting and drying of masonry units and mortars are unequal, differential volume changes may occur in the masonry that result in the formation or enlargement of cracks in the joints. The effects of about 12 cycles of alternate wetting and drying on 8 small masonry walls have been studied by measuring the permeability of the walls. The influence of exposure to local outdoor climatic conditions on permeability is also under study and the results will be described in a subsequent report.

Lyman J. Briggs, *Director.*

# Effects of Wetting and Drying on the Permeability of Masonry Walls

*by* CYRUS C. FISHBURN

CONTENTS



ABSTRACT

Since the volume changes resulting from the wetting and drying of masonry units and mortars are unequal, changes in the moisture content of a masonry wall may produce differential volume changes between the units and the mortar, resulting in the formation or enlargement of cracks in the joints. The effects of changes in the moisture content of 8 small masonry walls were studied by measuring the permeability of the walls during each of about 12 cycles of wetting and drying. The walls were wetted by applying water to the exposed face simulating an exposure to a wind-driven rain. The specimens were not subjected to freezing during wetting or drying. Five of the walls were of all-brick construction, one was a stucco-faced wall, and two were faced with brick and backed with hollow units. There was no significant change in the permeability of the walls resulting from the exposure to wetting and drying.

## I. INTRODUCTION

Masonry building walls are frequently exposed to wind-driven rains that saturate the exposed faces. Since mortars and some masonry units expand during wetting and shrink in drying, it is probable that differential volume changes occur between the units and the mortar joints in those portions of the walls subjected to wetting and drying. Such volume changes may result in the formation or enlargement of cracks in the masonry that permit the penetration of water into or through the wall. The linear expansions resulting from the immersion of dry and aged specimens of masonry materials in water are usually within the following limits:

| Material | Linear expansion (%) |
|---|---|
| Bricks [a, b] | 0 to 0.01. |
| Mortars and concretes [a, b, c, d, e] | 0.02 to 0.10. |
| Brick masonry [e] | 0.015 to 0.020. |

[a] L. A. Palmer, *Volume changes in brick masonry materials*, J. Am. Ceram. Soc. **14**, 541 (1931).

[b] R. E. Stradling, Effects of moisture changes on building materials, Bul. 3 Brit. Bldg. Research Board.

[c] R. E. Davis, Proc. Am. Soc. Testing Materials **30**, 668, appendix 13 (1930).

[d] W. K. Hatt and R. E. Mills, Bul. 34, Eng. Exp. Sta. Purdue Univ., p. 18 (1928).

[e] R. E. Davis and G. E. Troxell, Proc. Am. Conc. Inst. 25, 210 (1929).

Tests have been made on small masonry walls at the National Bureau of Standards to determine the possible effects of exposures to heating and cooling [1] and to wetting and drying on permeability; this paper reports only the effects of alternate wetting and drying.

## II. DESCRIPTION OF THE WALLS

Eight walls, about 40 in. long and 50 in. high, were selected from a group previously tested for permeability and described in a publication [2] of the National Bureau of Standards.

[1] C. C. Fishburn and P. Petersen, Effect of Heating and Cooling on the Permeability of Masonry Walls, NBS Building Materials and Structures Report BMS41 (1940).

[2] C. C. Fishburn, D. Watstein, D. E. Parsons, Water Permeability of Masonry Walls, NBS Building Materials and Structures Report BMS7 (1938).

Five of the walls were of all-brick construction, one was a stucco-faced wall, and two were faced with brick and backed with hollow units. Two kinds of brick, one stucco facing, three kinds of hollow units, and four mortars were represented in the group of eight specimens. The wall thicknesses, the types of workmanship, and the kinds of materials used, are given in table 1. The designations appearing in the last column of table 1 will be used to describe the walls in a subsequent table.

TABLE 1.—*Description of the walls* [a]

| Wall [b] | Nominal thickness | Kind of facing | Kind of backing | Kind of mortar | Designation [c] |
|---|---|---|---|---|---|
| | *in.* | | | | |
| 14 | 8 | Brick *a* | Brick *a* | 1 | aa1 |
| 60 | 8 | do | do | 2 | aa2 |
| 58 | 8 | do | do | 3 | aa3 |
| 51 | 8 | do | do | 4 | aa4 |
| A6 | 12 | Brick *b* | Brick *b* | 2 | bb2 |
| A5 | 12 | do | Block *m* | 2 | bm2 |
| 10 [d] | 12 | do | Tile *d* | 2 | bd2 |
| 7 [d] | 9 | Stucco | Tile *j* | 2 | sj2 |

[a] All walls were of workmanship *A* as described in BMS7 Water Permeability of Masonry Walls, except wall 10, which was of workmanship E.
[b] The wall numbers correspond to the original wall numbers in BMS7.
[c] The first two letters denote the kind of masonry units used in the facings and backings respectively. The numbers denote the kind of mortar used.
[d] Wall not flashed.

## 1. MATERIALS

Since complete information on the methods of construction and the kind of materials used in these walls is included in the publication BMS7, only brief descriptions are given in this paper. The linear expansions or contractions resulting from changes in the moisture content of the materials or of the walls were not determined.

*Brick.*—Brick *a*, used in walls 14, 60, 58, and 51 (table 1), was a low-absorptive side-cut fire-clay brick having an absorption during a 24-hr cold-water immersion of 0.4 percent by weight. Brick *b* was a side-cut shale brick having an absorption of 8 percent.

*Stucco.*—The stucco facing of wall 7 was mixed in the weight proportions of 1 part of portland cement to 3 parts of building sand, and it contained ammonium stearate in an amount equal to 0.2 percent of the cement. Two coatings, each from ⅜ to ½ in. thick, were applied 24 hr apart to the tile backing of this wall.

*Hollow-Unit Backings.* Block *m*, used in wall *A5*, was a gravel-concrete block 8 by 12 by 8 in. laid on end. Structural clay tile *d*, used in wall 10, was a 6-cell, double-shell end-bearing unit, the stretchers being 8 by 12 by 10½ in. Structural clay tile *j* was an 8 by 12 by 12 in. 6-cell unit laid on the side.

*Mortar.*—The physical properties of the mortar are given in table 2.

TABLE 2.—*Physical properties of mortars*

| Properties of mortars | Mortar 1 | Mortar 2 | Mortar 3 | Mortar 4 [a] |
|---|---|---|---|---|
| Proportions of cement, lime, and sand: | | | | |
| By dry weight | 1:0.11:2.6 | 1:0.42:5.1 | 1:0.85:7.7 | 1:0.42:5.1 |
| By volume [b] | 1:0.25:3 | 1:1:6 | 1:2:9 | 1:1:6 |
| Average water content; percentage by weight of dry materials | 19.3 | 22.6 | 23.7 | 22.6 |
| Compressive strength in 28 days (lb/in.$^2$) [c] | 2,850 | 640 | 250 | 530 |
| Flow after 1 minute of suction on porous base (percentage) [d] | 86 | 95 | 97 | 95 |

[a] Mortar 4 contained 0.2 percent of ammonium stearate by weight of cement plus dry hydrated lime.
[b] Proportioning was by weight, assuming portland cement weighs 94 lb/ft $^3$, dry hydrated lime 40 lb/ft $^3$, and that 1 ft $^3$ of loose damp sand contains 80 lb of dry sand.
[c] Cured according to Federal Specification SS-C-181.
[d] Test made on a mortar having an initial flow of 110 percent. Federal Specification SS-C-181a.

## 2. WORKMANSHIP

Workmanship *A* was used in the construction of all of the walls except wall 10, which was of workmanship *E*. For workmanship *A*, all joints were filled with mortar. Workmanship *E* was similar to *A*, except that no mortar was placed in the central 3 in. of both the bed and head joints of the tile backing. Both workmanships *A* and *E* are described in greater detail in BMS7.

All walls, except 7 and 10, contained copper flashings so placed as to collect leakage passing either through the wall or dropping between the wythes. Because of the absence of those flashings in walls 7 and 10, it could not be determined if moisture appearing on the supporting channels at the back of the walls during a test had penetrated the wall facings or had leaked through the mortar joints between the walls and the channels.

# III. METHOD OF TEST

The extent to which exterior masonry building walls are affected by wetting and drying depends greatly upon their permeability, or their resistance to penetration by heavy wind-driven rains. Walls having a comparatively low resistance may become permeated with water within a few hours. Others, having a high resistance, may become wetted only on the exposed surface. The resistance to rain penetration of the group of walls described in this report was comparatively high as compared with that of walls of ordinary or speculative building construction, such as workmanship *B*, described in BMS7.

The wetting exposure and the subsequent drying that the test walls received during each cycle of wetting and drying provided a range of moisture content in the masonry much greater than would occur in most building walls of like construction. Rain and wind storms of an intensity simulating the wetting exposure given the test walls are infrequent and rarely last longer than a few hours. The test walls were thoroughly dried to nearly constant weight after each wetting exposure.

### 1. The Wetting Exposure

All of the walls, with the exception of *A6* (broken at the end of 5 cycles), were given 10 or more cycles of wetting and drying, at temperatures above freezing. The wetting exposure is described on page 12 of BMS7 (Heavy Rain Test) and was designed to simulate the effects of a windstorm accompanied by a heavy rain. Each wall was supported on metal skids and clamped into position so that the face formed one side of the inner walls of an airtight pressure chamber. Water from a perforated metal tube was applied to the face of the wall at the rate of about 40 gal/hr. An air pressure of 10 lb/ft $^2$ above atmospheric pressure was maintained within the chamber. The wetting exposure was usually continued for at least 1 day after the first penetration of moisture through the wall, or for a maximum period of 1 week. The relative humidity in the testing room averaged about 70 percent but fluctuated somewhat with seasonal changes. In addition, also, the water applied to the walls (although heated during the winter months) was usually at a lower temperature than that of the air in the testing room. It is possible, therefore, that after one or more days of exposure, the backs of some of the walls attained dew-point temperature and condensation was deposited upon them. However, during test *B* (see table 3) the temperatures of both the water and the air in the testing room were controlled and there was no possibility of condensation forming on the backs of the walls, even though the average relative humidity was about 80 percent.

### 2. Drying the Walls

After they were wetted, the walls were placed in the drying room and bathed in heated air, circulated by fans. Fresh air was constantly drawn into the drying room from outside and heated to a temperature of 40° to 50° F above the daily mean outside air temperature. The walls remained in the drying room until the rate of moisture loss was less than 3 lb (from 0.2 to 0.4 percent of the dry weight) in 7 days.

### 3. The Observations

Data on the permeability of the walls were obtained from observations made during the wetting exposures. The following observations were obtained:

Elapsed time for the appearance of moisture (dampness) on the backs of the walls.

Elapsed time for the appearance of visible water on the backs of the walls.

Elapsed time for leakage to occur on the lower flashings.

Maximum rates of leakage, if any.

Extent of damp areas on the backs of the walls after an exposure of 1 day.

Observations were made at frequent intervals during working hours and usually once each night. Results of the observations are given in table 3. Data from tests made both prior to and after the wetting and drying cycles are included in the table. Test *A* corresponds to the "Heavy Rain Test," and data obtained from it are discussed in report BMS7. The average age of all the walls at the start and finish of the wetting and drying cycles was 10 and 22 months, respectively. Test *B* was made on five walls, aged 46 months, that had been stored outside for 2 years after the completion of the wetting exposures referred to by number in table 3.

TABLE 3.—*Data obtained from permeability exposures*

| Wall | Designation | Exposure number | Duration of exposure | Time to failure as indicated by— Damp through wall | Visible water through wall | Leak from lower flashing | Area damp in 1 day | Maximum rate of leakage per hr | Rating [a] |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Days* | *hr* | *hr* | *hr* | % | *Liters* | |
| 14 | aa1 | A | 6 | 134±6 | --- | --- | 0 | 0 | E |
| | | 1 | 7 | 91±5 | --- | --- | 0 | 0 | G |
| | | 2 | 4 | 89±7 | --- | --- | 0 | 0 | G |
| | | 3 | 3 | 51±2 | --- | --- | 0 | 0 | G–E |
| | | 4 | 7 | 112±5 | --- | --- | 0 | 0 | E |
| | | 5 | 7 | 123±1 | --- | --- | 0 | 0 | G |
| | | 6 | 7 | --- | --- | --- | 0 | 0 | E |
| | | 7 | 6 | 111±5 | --- | --- | 0 | 0 | G |
| | | 8 | 8 | 86±6 | --- | --- | 0 | 0 | G |
| | | 9 | 5 | 102±1 | --- | --- | 0 | 0 | G |
| | | 10 | 7 | 111±6 | --- | --- | 0 | 0 | G |
| | | B | 5 | 114±3 | --- | --- | 0 | 0 | E |
| 60 [b] | aa2 | A | 3 | 58±1 | --- | --- | 8 | 0 | G |
| | | 1 | 3 | 41±3 | --- | --- | 4 | 0 | G |
| | | 2 | 5 | 57±2 | --- | --- | 5 | 0 | G |
| | | 3 | 3 | 63±6 | --- | --- | 0 | 0 | G |
| | | 4 | 4 | 62±6 | --- | --- | 4 | 0 | G |
| | | 5 | 4 | 62±6 | --- | --- | 0 | 0 | G |
| | | 6 | 3 | 38±6 | --- | --- | 6 | 0 | G |
| | | 7 | 3 | 39±6 | --- | --- | 3 | 0 | G |
| | | 8 | 2 | 14±6 | --- | --- | 7 | 0 | G |
| | | 9 | 2 | 39±6 | --- | --- | 3 | 0 | G |
| | | 10 | 2 | 39±6 | --- | --- | 1 | 0 | G |
| 58 [d] | aa3 | A | 1 | 5.0 | --- | --- | 20 | 0 | G |
| | | 1 | 2 | 19±3 | --- | --- | 70 | 0 | F |
| | | 2 | 2 | 13±4 | --- | --- | 44 | 0 | G |
| | | 3 | 4 | 52±1 | --- | --- | 0 | 0 | G |
| | | 4 | 3 | (c) | (c) | (c) | (c) | (c) | (c) |
| | | 5 | 2 | 14±6 | --- | --- | 8 | 0 | G |
| | | 6 | 5 | 39±6 | --- | --- | --- | 0 | G |
| | | 7 | 2 | 15±6 | --- | --- | 79 | 0 | F |
| | | 8 | 2 | 15±6 | --- | --- | 90 | 0 | F |
| | | 9 | 4 | 10±2 | --- | --- | 90 | 0 | F |
| | | 10 | 2 | 15±6 | --- | --- | 95 | 0 | F |
| | | 11 | 1 | 18±4 | --- | --- | 48 | 0 | G |
| | | B | 2 | 24±1 | --- | --- | 3 | 0 | G |
| 51 | aa4 | A | 1 | 0.37 | --- | --- | 9 | 0 | G |
| | | 1 | 2 | .18 | --- | --- | 4 | 0 | G |
| | | 2 | 2 | .25 | --- | --- | 7 | 0 | G |
| | | 3 | 3 | .33 | --- | --- | 8 | 0 | G |
| | | 4 | 5 | 1.7 | --- | --- | 3 | 0 | G |
| | | 5 | 3 | 4.5 | --- | --- | 12 | 0 | G |
| | | 6 | 2 | 6.7 | --- | --- | 2 | 0 | G |
| | | 7 | 2 | 5.5 | --- | --- | 5 | 0 | G |
| | | 8 | 2 | 3.4 | --- | --- | 5 | 0 | G |
| | | 9 | 2 | 15±6 | --- | --- | 12 | 0 | G |
| | | 10 | 2 | 15±6 | --- | --- | 1 | 0 | G |
| | | 11 | 1 | 3 | --- | --- | 12 | 0 | G |
| | | B | 4 | 10±3 | --- | --- | 2 | 0 | G |
| A6 | bb2 | A | 1 | 9±2 | --- | --- | 10 | 0 | G |
| | | 1 | 2 | 23 | --- | --- | 1 | 0 | G |
| | | 2 | 3 | 28 | --- | --- | 0 | 0 | G |
| | | 3 | 3 | 25 | --- | --- | 0 | 0 | G |
| | | 4 | 3 | 24 | --- | --- | 0 | 0 | G |
| | | 5 | 2 | 26 | --- | --- | 10 | 0 | G |
| | | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (e) |
| A5 | bm2 | A | 1 | 1.3 | 15±3 | 18±3 | 35 | 0.1 | F |
| | | 1 | 1 | 0.5 | 15±6 | 15±6 | 85 | 0.4 | F |
| | | 2 | 2 | 3.3 | 39±6 | --- | 14 | 0 | G |
| | | 3 | 2 | 4.1 | --- | --- | 6 | 0 | G |
| | | 4 | 2 | 4.2 | --- | --- | 10 | 0 | G |
| | | 5 | 2 | 10±3 | --- | --- | 4 | 0 | G |
| | | 6 | 2 | 0.4 | 15±6 | --- | 70 | 0 | F |
| | | 7 | 2 | .7 | 15±6 | 39±6 | 45 | 0.6 | F |
| | | 8 | 1 | 1.2 | --- | --- | 17 | 0 | G |
| | | 9 | 2 | 40±6 | --- | --- | 0 | 0 | G |
| | | 10 | 5 | 18±4 | --- | --- | 1 | 0 | G |
| | | B | 5 | 18±4 | --- | --- | 1 | 0 | G |

[a] Ratings are arbitrary and are the same as those given in report BMS7. The absence of flashings at the bottom allowing moisture to penetrate upward into the wall, or the formation of condensation on the back, may have lowered some of the performance ratings of the less permeable walls from *E* (Excellent) to *G* (Good).

[b] Break in wall near first header course between fifth and sixth tests (repaired).

[c] No data obtained.

[d] Repaired below first header course, between exposures 3 and 4.

[e] Wall broken in handling.

TABLE 3.—*Data obtained from permeability exposures*—Continued

| Wall | Designation | Exposure number | Duration of exposure | Time to failure as indicated by— Damp through wall | Visible water through wall | Leak from lower flashing | Area damp in 1 day | Maximum rate of leakage per hr | Rating [a] |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Days* | *hr* | *hr* | *hr* | % | *Liters* | |
| 10 | bd2 | A | 4 | 61±6 | --- | --- | 5 | 0 | G |
| | | 1 | 3 | 39±6 | --- | --- | 20 | 0 | G |
| | | 2 | 4 | 65±5 | --- | --- | 20 | 0 | G |
| | | 3 | 4 | 62±6 | --- | --- | 15 | 0 | G |
| | | 4 | 4 | 63±6 | --- | --- | 12 | 0 | G |
| | | 5 | 7 | 85±5 | --- | --- | 12 | 0 | G |
| | | 6 | 3 | 38±6 | --- | --- | 10 | 0 | G |
| | | 7 | 2 | 15±6 | --- | --- | 17 | 0 | G |
| | | 8 | 3 | 63±6 | --- | --- | 12 | 0 | G |
| | | 9 | 6 | 87±6 | --- | --- | 10 | 0 | G |
| | | 10 | 5 | 52±3 | --- | --- | 25 | 0 | G |
| 7 | sj2 | A | 7 | 144±15 | --- | --- | 0 | 0 | E |
| | | 1 | 4 | 50±3 | --- | --- | 5 | 0 | G |
| | | 2 | 2 | 19±4 | --- | --- | 5 | 0 | G |
| | | 3 | 4 | 50±2 | --- | --- | 1 | 0 | G |
| | | 4 | 6 | 112±5 | --- | --- | 2 | 0 | G |
| | | 5 | 4 | 63±6 | --- | --- | 10 | 0 | G |
| | | 6 | 5 | 86±6 | --- | --- | 2 | 0 | G |
| | | 7 | 3 | 38±6 | --- | --- | 2 | 0 | G |
| | | 8 | 5 | 63±6 | --- | --- | 3 | 0 | G |
| | | 9 | 5 | 90±10 | --- | --- | 2 | 0 | G |
| | | 10 | 5 | 111±6 | --- | --- | 2 | 0 | G |
| | | B | 5 | 58±2 | --- | --- | 1 | 0 | E |

## IV. EFFECTS OF WETTING AND DRYING ON THE PERMEABILITY OF THE WALLS

Masonry wall constructions may show a wide range in permeability, as is indicated in table 4 of report BMS7. In this table the time interval required for the penetration of moisture or leakage through the different test walls ranged from a few minutes for the most permeable specimens to one or more weeks for the least permeable ones.

Since visible water, extensive damp areas on the back, or leakage through a wall might injure the finished interior of a building or damage plaster applied directly to a wall, the rating of the walls was judged by their condition at the end of the exposure periods, time of first penetration of moisture being considered a minor factor. The arbitrary wall ratings defined on page 13 of BMS7 are largely dependent upon the condition of the wall at the end of 1 day's exposure.

The wetting exposure given the test walls is more severe than the natural exposure to which most building walls are subjected, and the test exposures were often continued for periods much longer than the duration of combined heavy wind and rain storms. Although test exposures lasting more than 1 or 2 days, may produce valuable data for comparing the performances of different wall constructions, their practical value diminishes rapidly with continuation beyond 24 hours.

### 1. All-Brick Walls

The 8-in. brick walls Nos. 14, 60, and 58 were alike except for the kind of mortar. As the bricks did not transmit water during the exposures, the tests were measures of the water permeability of the joints, wall 14, containing mortar 1 richest in portland cement, being the least permeable and wall 58, containing the high lime mortar 3, being the most permeable. The proportion of the damp to the total areas, at the end of 1 day, on the backs of walls 60, 58, and *A6* fluctuated from test to test (especially wall 58), but did not show a consistent tendency to increase or to decrease.

The first failure on the back of wall 51, during exposures 1, 2, and 3, was a small leak that stopped flowing within 1 hr after starting the tests. There was no leakage from this wall during any of the later exposures, and the time intervals for the first appearance of dampness are considerably longer for the last 8 exposures than for the earlier ones. Although the percentages of damp areas did not show a consistent tendency to decrease, the increase in the time for damp penetration indicated that the permeability of wall 51 decreased slightly during the wetting and drying exposures. The performances of the brick walls would be rated good, according to the ratings in BMS7, with the exception of some excellent performances for wall 14 (exposure numbers *A*, 4, 6, and *B*) and some fair ones for wall 58 (exposure numbers 1, 7, 8, 9, and 10).

The data in table 3 show that there was no significant or consistent change in permeability resulting from exposure of the all-brick walls to alternate cycles of wetting and drying.

### 2. Walls With Brick Facings and Hollow-Unit Backings

Wall 10 was not flashed at the bottom, and water appeared on the supporting channel within 1 or 2 hr after starting each exposure. The performance of this wall was fairly uniform for all test exposures and would be rated good if the possibility of leakage through the wall were eliminated.

The performance of wall *A5*, table 3, was better during the last three exposures, 9, 10, and *B*, than for any of the earlier ones; there was some leakage noted from the wall during exposures *A*, 1, and 7. According to the ratings in BMS7, the wall could be rated good for all test exposures except *A*, 1, 6, and 7. Although the data are meager, there is, however, a definite indication that the permeability of wall *A5* was slightly reduced, but not significantly changed, by exposure to wetting and drying.

### 3. Wall With Stucco Facings

The performance of wall 7 was comparable to that of the least permeable brick wall, 14, and could have been rated excellent for exposure numbers *A* and *B*. Wall 7 was not flashed, and moisture (damp areas) appeared at the bottom of the wall within 24 hr after the start of each exposure. The time intervals (table 3) for the first appearance of moisture on the back of the wall are for areas that appeared above the damp area located along the supporting channel. The data in table 3 show no significant change in performance during any of the test exposures, and there is no evidence of any definite increase in permeability resulting from the exposure of the stucco-faced wall to wetting and drying.

## V. CONCLUSIONS

These conclusions pertain to the effect of alternate wetting and drying on the permeability of a small group of masonry walls. The walls were not subjected to freezing and thawing during the wetting and drying exposures, and changes in their linear dimensions were not restrained by adjacent structural members. The exposures, therefore, tended to cause differential movements between the different materials in the walls and presumably tended to cause the separation of these materials and the formation of cracks. However, these exposures did not simulate all the conditions which sometimes cause a few large structural cracks in a large wall.

The exposure to alternate wetting and drying had no significant effect on the permeability of 8-in. low-absorptive brick masonry walls.

Although the data are meager, the permeability of walls with brick facings and hollow-unit backings was slightly but not significantly reduced by exposure to alternate wetting and drying.

There was no significant change in the permeability of a stucco-faced wall subjected to alternate wetting and drying.

Washington, April 2, 1940.

BUILDING MATERIALS AND STRUCTURES REPORTS

On request, the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., will place your name on a special mailing list to receive notices of new reports in this series as soon as they are issued. There will be no charge for receiving such notices.

An alternative method is to deposit with the Superintendent of Documents the sum of $5.00, with the request that the reports be sent to you as soon as issued, and that the cost thereof be charged against your deposit. This will provide for the mailing of the publications without delay. You will be notified when the amount of your deposit has become exhausted.

If 100 copies or more of any paper are ordered at one time, a discount of 25 percent is allowed.

Send all orders and remittances to the *Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.*

The following publications in this series are available by purchase from the Superintendent of Documents at the prices indicated:

| | | |
|---|---|---|
| BMS1 | Research on Building Materials and Structures for Use in Low-Cost Housing | 10¢ |
| BMS2 | Methods of Determining the Structural Properties of Low-Cost House Constructions | 10¢ |
| BMS3 | Suitability of Fiber Insulating Lath as a Plaster Base | 10¢ |
| BMS4 | Accelerated Aging of Fiber Building Boards | 10¢ |
| BMS5 | Structural Properties of Six Masonry Wall Constructions | 15¢ |
| BMS6 | Survey of Roofing Materials in the Southeastern States | 15¢ |
| BMS7 | Water Permeability of Masonry Walls | 10¢ |
| BMS8 | Methods of Investigation of Surface Treatment for Corrosion Protection of Steel | 10¢ |
| BMS9 | Structural Properties of the Insulated Steel Construction Co.'s "Frameless-Steel" Constructions for Walls, Partitions, Floors, and Roofs | 10¢ |
| BMS10 | Structural Properties of One of the "Keystone Beam Steel Floor" Constructions Sponsored by the H. H. Robertson Co. | 10¢ |
| BMS11 | Structural Properties of the Curren Fabrihome Corporation's "Fabrihome" Constructions for Walls and Partitions | 10¢ |
| BMS12 | Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc | 15¢ |
| BMS13 | Properties of Some Fiber Building Boards of Current Manufacture | 10¢ |
| BMS14 | Indentation and Recovery of Low-Cost Floor Coverings | 10¢ |
| BMS15 | Structural Properties of "Wheeling Long-Span Steel Floor" Construction Sponsored by Wheeling Corrugating Co | 10¢ |
| BMS16 | Structural Properties of a "Tilecrete" Floor Construction Sponsored by Tilecrete Floors, Inc | 10¢ |
| BMS17 | Sound Insulation of Wall and Floor Constructions | 10¢ |
| BMS18 | Structural Properties of "Pre-Fab" Constructions for Walls, Partitions, and Floors Sponsored by the Harnischfeger Corporation | 10¢ |
| BMS19 | Preparation and Revision of Building Codes | 15¢ |
| BMS20 | Structural Properties of "Twachtman" Constructions for Walls and Floors Sponsored by Connecticut Pre-Cast Buildings Corporation | 10¢ |
| BMS21 | Structural Properties of a Concrete-Block Cavity-Wall Construction Sponsored by the National Concrete Masonry Association | 10¢ |
| BMS22 | Structural Properties of "Dun-Ti-Stone" Wall Construction Sponsored by the W. E. Dunn Manufacturing Co | 10¢ |
| BMS23 | Structural Properties of a Brick Cavity-Wall Construction Sponsored by the Brick Manufacturers Association of New York, Inc | 10¢ |
| BMS24 | Structural Properties of a Reinforced-Brick Wall Construction and a Brick-Tile Cavity-Wall Construction Sponsored by the Structural Clay Products Institute | 10¢ |
| BMS25 | Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs | 15¢ |
| BMS26 | Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc | 10¢ |
| BMS27 | Structural Properties of "Bender Steel Home" Wall Construction Sponsored by The Bender Body Co | 10¢ |
| BMS28 | Backflow Prevention in Over-Rim Water Supplies | 10¢ |

[List continued on cover page IV]

## BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page III]