NRC Publications Archive Archives des publications du CNRC

Study of efflorescence on experimental brickwork piers Ritchie, T.

This publication could be one of several versions: author's original, accepted manuscript or the publisher's version. /
La version de cette publication peut être l'une des suivantes : la version prépublication de l'auteur, la version
acceptée du manuscrit ou la version de l'éditeur.

Publisher's version / Version de l'éditeur:

Journal of the American Ceramic Society, 38, 10, pp. 357-361, 1955

NRC Publications Record / Notice d'Archives des publications de CNRC:

<https://nrc-publications.canada.ca/eng/view/object/?id=5e200877-a7b1-4205-a26b-f709f4fa5410>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=5e200877-a7b1-4205-a26b-f709f4fa5410>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

National Research
Council Canada

Conseil national de
recherches Canada

Canada

TH1
N21r2
no. 19
c. 2

BLDG

18504
ANALYZED

STUDY OF EFFLORESCENCE ON EXPERIMENTAL BRICKWORK PIERS

By T. Ritchie

RESEARCH PAPER NO. 19

Division of Building Research,
National Research Council,
Ottawa, Ontario, Canada

[Reprinted from the *Journal of the American Ceramic Society*, 38 [10] 357-361 (1955).]

PRICE 10 CENTS

N.R.C. 3773

ANALYZED

Study of Efflorescence on Experimental Brickwork Piers

by T. RITCHIE

Division of Building Research, National Research Council, Ottawa, Ontario, Canada

Efflorescence on brickwork piers made of three types of brick and six mortars appeared to depend mainly on (a) the Portland cement content of the mortar, (b) the type of brick, and (c) the season of the year. Efflorescence formed in the cold part of the year and was absent in the summer. Portland cement substituted for lime in mortars contributed to efflorescence; however, the amount of efflorescence depended also on the type of brick (probably on the pore structure).

I. Introduction

THE purpose of this paper is to describe the occurrence of efflorescence on certain brickwork structures in relation to the properties of the brick and mortars used and to some other factors.

In building science the term "efflorescence" means the formation of deposits of salts on the surfaces of masonry as a result of exposure to the weather. Usually efflorescence is considered a problem only because it disfigures the masonry; the disfigurement is often extreme, particularly when there is contrast of color between the salt deposits and the masonry material, such as white efflorescence on red brick.

It is generally considered that when the masonry becomes wet, such as from rain, soluble salts in it are taken into solution. Evaporation of this moisture subsequently takes place, the solution being transported to the surface of the

masonry, where its evaporation results in the formation of salt deposits.

Many different salts have been found to form efflorescence on masonry. Sulfate salts of sodium, potassium, calcium, or magnesium have frequently been detected.¹ On brickwork, efflorescence containing the carbonates of sodium and potassium, and ferrous sulfate, has been described.^{1(b)} Chloride and nitrate salts have been found in efflorescence on occasion,^{1(a)} and sodium vanadate and various silicates have been mentioned^{1(c)} as components of efflorescence on masonry.

It is generally considered that substances capable of forming efflorescence may originate in the masonry units, in the

Received February 28, 1955.

This paper is a contribution from the Division of Building Research, National Research Council (Report No. 64), and is published with the approval of the Director.

The author is assistant research officer, Division of Building Research, National Research Council.

¹ (a) Great Britain Department of Scientific and Industrial Research; Report of Building Research Board with Report of Director of Building Research, 1927.

(b) B. Butterworth, "Efflorescence and Staining of Brickwork," *Brick Bull.*, 1, No. 11, December 1950 (published by the National Federation of Clay Industries, London).

(c) F. O. Anderegg, "Efflorescence," *ASTM Bull.*, 1952, No. 185, TP 155-61; *Ceram. Abstr.*, 1953, April, p. 62j.

mortar, or in soil in contact with the masonry (into which they are drawn by the movement of moisture). They may also form in the masonry from atmospheric pollution or as the products of chemical changes in the masonry units or mortar.

Efflorescence frequently forms on masonry shortly after its erection. The intensity of the efflorescence usually diminishes with time as the masonry is washed by rain.^{1(a), 1(b)} After its formation, the efflorescence may disappear and reappear during the year,^{1(b)} and it is more pronounced and more prevalent on masonry in the coolest seasons of the year.^{1(a), 2}

Efflorescence has formed on occasion when Portland cement was used in masonry mortar, whereas under similar conditions with lime mortar no efflorescence occurred. The efflorescence has been attributed^{1(a), 2} to alkaline material in the Portland cement.

Some clay and shale building brick appear to be more susceptible to efflorescence than others^{1(b), 3}; in different brick the amount of salts which can form efflorescence varies widely. Even if the salts of efflorescence did not originate in them, some brick apparently possess certain physical properties by which efflorescence originating in other sources may form more easily on them.

II. Experimental Brickwork Structures

Eighteen brickwork piers were erected in the summer of 1952 in Ottawa for studies of some aspects of the weathering of certain masonry materials. Three types of brick were used in the piers. For each type, six mortars were used, which varied in composition from lime and sand only as one extreme

(Text continued on page 360)

² R. K. Robertson, "Efflorescence," *J. Can. Ceram. Soc.*, **13**, 40-43 (1944); *Ceram. Abstr.*, **23** [9] 151 (1944).

³ W. E. Brownell, "Fundamental Factors Influencing Efflorescence of Clay Products," *J. Am. Ceram. Soc.*, **32** [12] 375-89 (1949).

Fig. 1. Form of brickwork piers.

Table I. Properties of the Brick

Property determined	Range in value		
	Brick A	Brick B	Brick C
Initial rate of absorption (gm.)*	54.5 to 104.7 (avg. 75.5)	2.2 to 6.2 (avg. 3.8)	35.2 to 41.9 (avg. 38.3)
Absorption 24 H.C. (%)†	6.2 to 10.3	0.9 to 3.6	11.8 to 13.4
Absorption 5 H.B. (%)‡	8.5 to 13.2	2.4 to 5.2	14.5 to 15.8
Saturation coefficient§	0.73 to 0.80	0.38 to 0.71	0.81 to 0.87
Compressive strength (lb./sq. in.)	4630 to 6420	17,100 to >17,600	5820 to 6040

* Amount, in grams, of water absorbed by a dry brick when placed in $\frac{1}{8}$ in. of water for one minute (flat side down), corrected for a standard area of 30 sq. in.

† Amount of water absorbed by a brick, expressed as a percentage of its dry weight, when the brick is immersed in water, at room temperature, for 24 hours.

‡ Amount of water absorbed by a brick, expressed as a percentage of its dry weight, when after immersion for 24 hours it is immersed in boiling water for 5 hours and then cooled to room temperature in the water for 18 hours.

§ Ratio of the amounts of water absorbed by a brick during immersion in water at room temperature for 24 hours and during immersion in boiling water for 5 hours.

Fig. 2. Arrangement of piers (south side).

Fig. 3. Comparison of piers of brick A.

Fig. 4. Comparison of piers of brick B.

Fig. 5. Comparison of piers of brick C.

to Portland cement and sand only as the other extreme. The cementing material of the four intermediate mortars was a mixture, in various proportions, of Portland cement and lime. In all mortars a ratio of cementing material to sand of one to three, by volume, was maintained. Each pier was of solid brickwork and was approximately 5 ft. high, 2 ft. long, and 1 ft. thick. The form is shown in Fig. 1. The bottom four courses were separated from the remainder of the pier by a sheet of copper foil and tarred fiber, and the concrete cap was similarly separated from the brickwork. This damp proofing was inserted at the bottom to prevent rise of ground moisture into the pier, and at the top to prevent downward movement of moisture. The piers were placed about 5 ft. apart and were arranged in rows of six, one row for each type of brick. The arrangement is shown in Fig. 2.

The three types of brick used are designated A, B, and C. All were red in color, although differing in shade, and all were solid (not cored or perforated). The type A brick were made by the dry-press method and were smooth-faced; types B and C were made by the stiff-mud method and had wire-cut exposure surfaces. Some properties of samples of the three types of brick, determined by standard methods,⁴ are shown in Table I. The range in values of the brick properties are, except for compressive strength, for ten samples.

The brick were laid in six different mortars. The proportions of the mortar components are shown in Table II. In all the mortars a ratio of cementing material to sand of one to three, by volume, was maintained. The lime used was obtained by slaking a high-calcium quicklime. The putty thus made was stored for more than four months before use. The sand used was a local natural sand which has been employed extensively for masonry work in the Ottawa area. The particle-size grading was adjusted by the addition of certain fractions to conform to standard specification requirements.⁵

III. Occurrence of Efflorescence on the Piers

Efflorescence formed on several of the piers in the fall and winter following their construction in August 1952. Certain of the piers have remained free of efflorescence and others have been affected by it in varying degree (from very slightly to heavily marked).

During the year after the construction of the piers the efflorescence gradually diminished in intensity during the spring and early summer until it became unnoticeable even on the piers which had been heavily marked. In the late part of the year, however, the efflorescence again developed, and continued as a general condition throughout the late fall and winter. In the next summer (1954), a great decrease in the intensity of the efflorescence took place.

It has been noted on many occasions that the efflorescence has disappeared in rainy weather and has subsequently reappeared in dry weather. However, in the summer, even after a heavy wetting by rain, efflorescence did not develop after the change to dry weather. For any particular pier the efflorescence may form on all, or only some, of the sides, but it forms most frequently on the south side.

The piers in which brick A was used varied widely in the amount of efflorescence, as is shown in Fig. 3. The pier marked A1 has mortar composed of lime and sand; that marked A6 has mortar composed of Portland cement and sand. The mortar compositions of the intermediate piers correspond to those shown in Table II.

None of the piers of brick B were affected by efflorescence. These piers are shown in Fig. 4 and are arranged as to mortar composition in the same way as in Fig. 3. Some of the brick of these piers became stained, particularly with mortar of relatively high Portland cement content. Staining was caused by separation from the mortar, when the brick were laid of a slurry of cementing material which flowed over some of the brick faces.

Table II. Compositions of the Mortars

Components (by volume)
0.0 PC:1.0 L:3.0 S
0.2 PC:0.8 L:3.0 S
0.4 PC:0.6 L:3.0 S
0.6 PC:0.4 L:3.0 S
0.8 PC:0.2 L:3.0 S
1.0 PC:0.0 L:3.0 S

PC = Portland cement; L = lime; and S = sand.

Table III. Analysis of Efflorescence (%)

Component of sample	Pier A3	Pier A6
Na ₂ O	20.8	21.4
K ₂ O	6.7	10.9
SO ₄	53.9	59.2
Cl	(*)	(*)
CO ₃	(*)	(*)
MgO	(*)	(*)
CaO	5.3	5.4
Insoluble in water	14.9	5.0

* None detected.

The piers of brick C are compared in Fig. 5 and are arranged as to mortar composition in the same way as previously.

All the photographs of Figs. 3, 4, and 5 were taken on the same day in March 1954.

IV. Chemical Analysis of Efflorescence

Samples of the efflorescence on two piers of brick A were obtained by scraping the salts from the brick surfaces. Chemical analysis of these samples was carried out, with respect to the components listed in Table III.

The mortar of pier A3 consisted of 0.4 part Portland cement, 0.6 part lime, and 3.0 parts sand, by volume; the mortar of pier A6 consisted of 1.0 part Portland cement and 3.0 parts sand, by volume.

V. Discussion

The occurrence and amount of efflorescence on the piers appear to depend mainly on three factors: the composition of the mortar used, the properties of the brick used, and the weather conditions prevailing.

During two years following construction of the piers the efflorescence developed in the fall and winter and departed in the summer. This cycle was repeated subsequently.

This cycling occurrence of efflorescence appears to have been due in some way to differences in weather conditions throughout the year. Weather records,⁶ however, showed no great difference in rainfall between summer and winter. The rainfall in Ottawa for certain months of 1952 and 1953 is shown in Table IV. The weather records⁶ indicate, in addition, no appreciable difference in wind speed for the winter and summer months. There is, of course, wide variation in temperature throughout the year, and it has been postulated elsewhere² that the rate of drying of brickwork in cold weather is very slow, a condition said to be favorable for efflorescence.

⁴ "Standard Methods of Sampling and Testing Brick," A.S.T.M. Designation C 67-50; 1950 Supplement to Book of A.S.T.M. Standards, Part 3.

⁵ "Standard Specifications for Aggregate for Masonry Mortar," A.S.T.M. Designation C 144-44; A.S.T.M. Book of Standards, Part 3, 1949.

⁶ Meteorological Division, Department of Transport; Monthly Meteorological Summaries of Ottawa, Ontario.

Table IV. Rainfall in Ottawa for Certain Months of 1952 and 1953*

1952 rainfall (in.)		1953 rainfall (in.)		1953 rainfall (in.)	
October	1.99	June	2.60	October	1.16
November	2.04	July	1.95	November	1.16
December	2.21	August	2.51	December	2.42

* See footnote 6.

In connection with rate of drying as a factor in the formation of efflorescence, it is of interest to cite the problem in brickmaking of "dry-house scum," which is the concentration of salts at a drying surface when moist clay brick are dried before being fired. In dealing with this problem it has been noted,⁷ "Another means by which the scum may be prevented is to greatly increase the rate of drying of the green brick. If the drying progresses slowly, the evaporation takes place at the surface of the brick and any soluble salts will be concentrated there. If, however, the drying is hastened beyond a certain rate, the surface of the brick quickly becomes dry, and the balance of the moisture in the body is evaporated from below the surface and thus the bulk of the soluble salts will remain below the surface where they cannot produce any scumming." Rapid drying as a means of overcoming this problem also has been mentioned elsewhere.⁸

The occurrence and amount of efflorescence on the piers also appear to be a function of the composition of the mortar used and of the properties of the brick.

In the case of the piers of bricks A and C, the amount of efflorescence generally increased as the proportion of Portland cement in the mortar increased; the piers of brick C, however, were affected to a much lesser degree by efflorescence.

Marked differences in the amount of efflorescence on the piers occurred when the same mortar (of relatively high Portland cement content) was used with the three types of brick. Thus, with brick B no efflorescence developed; with brick C relatively slight efflorescence occurred; and with brick A relatively heavy efflorescence formed. Table I shows that the rate of water absorption of the brick varies greatly. Brick of type B (piers of which gave no efflorescence) are relatively low in rate of water absorption. Brick of type A (piers of which gave much efflorescence with mortars of high Portland cement content) are high in rate of absorption. Brick of type C (piers of which gave slight efflorescence) are relatively moderate in rate of absorption. The differences in water absorption rates undoubtedly reflect differences in the pore structures of the three types of brick used, which influenced greatly the liability of the various brick to be affected by efflorescence.

There was some indication that the concrete caps on the piers may have interfered in certain cases with the formation of efflorescence. This was so particularly with pier A1

(Fig. 3). The copper foil separating the cap from the brickwork was installed in two parts, designed to be overlapped. It has been found in some cases, however, such as shown in Fig. 6, that the two parts had become separated, or overlapped only slightly, so that the possibility of water movement into the top of the piers must be considered. In pier A1 efflorescence started to form just beneath the copper foil and gradually extended downward from that location. It has been observed frequently in other structures that brickwork beneath concrete window sills, or other concrete units, has been marked by efflorescence in the region adjacent to such a unit, whereas other parts of the wall have been free of efflorescence.

VI. Conclusions

This study confirms other experiences, which have been cited, that the composition of the mortar may considerably influence the occurrence of efflorescence on brickwork. When efflorescence formed on the piers studied in this work, it was in general more extensive and pronounced for the mortars of higher proportions of Portland cement. However, piers of different brick but with the same mortar of high Portland cement content were affected by efflorescence to markedly different extents; with one type of brick no efflorescence developed, with another a considerable amount, and with the third, only a slight amount.

The efflorescence on the piers studied was seasonal, being present in the fall, winter, and spring of the year, but disappearing in the summer. Temperature appears to be the factor controlling this cycle, possibly because of its effect on the rate of evaporation of moisture from the brickwork, whereby the salt deposits may be formed either within, or on the surface, of the masonry.

Acknowledgment

J.-M. Billy of the Division of Building Research, National Research Council, assisted in this study. The analysis of samples of efflorescence, shown in Table III, was carried out by E. C. Goodhue, Division of Applied Chemistry, National Research Council.

Fig. 6. Separation in copper foil beneath the concrete cap of a pier.

⁷ Joseph Keele, Investigations in 1921 of the Mines Branch, Department of Mines, Canada.

⁸ L. A. Palmer, "Cause and Prevention of Kiln and Dry-House Scum and of Efflorescence on Face-Brick Walls," *Bur. Standards Tech. Paper*, No. 370, 50 pp. (1928); *Ceram. Abstr.*, 7 [10] 687 (1928).