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ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois
John C. Frye, Chief

INDUSTRIAL MINERALS NOTES

Number 18, April 1964

PERMANENT EXPANSION IN BRICKS

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ABSTRACT

Bricks produced in Illinois and the clays from which they are made were tested to determine whether they were subject to sufficient expansion to cause structural damage when used in construction.

Sample bricks were taken from all Illinois brick plants, and test bars were made from the raw clays used by the manufacturers. The bars were fired at various temperatures. Both bricks and test bars were measured at intervals for 3½ years. Bricks stored in a controlled atmosphere were compared with bricks from the same kilns that had been kept outdoors.

Data indicate that expansion behavior depends on the type of clay used and on the temperature of firing; that expansion takes place rapidly in the first week after firing and diminishes thereafter; and that bricks fired at low temperatures expand most.

Expansion was not found to be an acute problem in Illinois-made bricks when proper precautions were taken by manufacturer and builder.

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INTRODUCTION

Bricks are one of the oldest and most beautiful of building materials as well as one of the best. When made of carefully selected and properly fired clays, bricks are stable and highly durable.

Damage attributed to permanent expansion of bricks due to adsorption of moisture has been reported in brick structures both in the United States and abroad. Undesirable expansion of ceramic material was first noted over 35 years ago in whiteware, in which it was found to cause crazing of glazes (Schurecht, 1928). Not until fairly recently was it considered as a cause of damage in masonry structures. McBurney (1954) reported that moisture expansion of ceramic building tile was responsible for damage to buildings in Virginia, Ohio, and Washington, D. C. Hosking et al. (1959) investigated permanent moisture expansion of Australian bricks, and reports of similar studies have come from other countries.

Much of the expansion damage reported in Illinois has been in buildings constructed of bricks made in other states. Few instances of expansion damage have been reported for Illinois bricks, but to determine whether bricks made in Illinois were subject to excessive expansion and, if so, what caused it and how it could be corrected, an Illinois State Geological Survey investigation was begun in 1960.

Detailed results of the tests are available to the manufacturers who provided materials for the experiments, but, as the data deal with specific materials and firing conditions and would not be of general interest, the following discussion presents only the significant findings.

TEST PROCEDURE

The first phase of the investigation, conducted by J. S. Hosking, W. E. Parham, and W. A. White, involved the testing of bricks and brick clays from 11 brick manufacturing plants in various parts of Illinois.

At each plant, five bricks were selected from each of six locations within both periodic and tunnel kilns while the bricks were warm. The dimensions of each brick were recorded on the following day, again at the end of the first week, after two weeks, at the end of the first, second, and third months, at 3-month intervals for the next 15 months, and at 6-month intervals for the rest of the 3½-year test period. All the bricks were stored in a room in which the relative humidity was kept between 50 and 60 percent and the temperature between 75° and 85° F.

Each manufacturer furnished a sample of the raw clay from which his bricks were made. At the Survey, 100 test bars were made from each sample. Bars also were made from two field samples of clay. Groups of eight from each 100 were fired at different temperatures. The firing temperatures ranged, at 50° C (90° F) intervals, from 800° C (1472° F) to either the fusion point or 1300° C (2372° F), whichever was reached first. Bars were removed from the furnace while they were warm and stored in the room with the controlled atmosphere. The test bars were measured at the same intervals as the manufacturers' bricks.

The second phase of the study, conducted by White, compared outdoor and indoor storage effects on brick expansion. Bricks were collected from the 10 Illinois plants not sampled in the first phase of the investigation. Six bricks were taken from each of six locations in periodic kilns and six from each of three locations in tunnel kilns. Two bricks from each location were stored in the room in which the temperature and humidity were controlled, and two bricks from each location were placed outdoors in a window well. The bricks of both groups were measured at the same intervals as those in the first phase but for a period of only 18 months.

RESULTS OF FIRING TESTS

The tests indicated that different clays, even when fired at the same temperature, show marked differences in expansion characteristics. Each clay also exhibits different expansion behavior for each temperature at which it is fired.

Detailed data are shown in figures 1 and 2 for the two clays that showed the two extremes of behavior—illite from Fithian, Illinois, and kaolin from Anna, Illinois. These clays were samples taken in the field by the geologists and do not represent raw materials used by any manufacturer.

The illite (fig. 1) was the most expansive clay studied. Its greatest expansion took place in the test bars fired at 900° C (1652° F). Forty percent of the expansion in bars fired at this temperature took place in the first week after firing, and by the end of the first 8 weeks 60 percent of the expansion had taken place. Expansion during the next 40 months was no greater than that of the initial week of the test.

The kaolin (fig. 2) was the most refractory clay studied. Although it expanded much less than the illite, the rates of expansion of the two clays were similar. Maximum expansion of the kaolin took place at temperatures ranging from 900° C (1652° F) to 1150° C (2102° F). Over 30 percent of the expansion took place in the first week and 45 percent in the first 8 weeks. The remaining 55 percent of the expansion for the test period was spread out over the next 40 months.

Like the illite and kaolin, the other clays tested exhibited much of their expansion soon after the bars were removed from the kiln.

Maximum expansion for most of the buff-burning clays occurred among those fired at 1000° C (1832° F). For red-burning clays, maximum expansion after firing took place in the bars fired at 900° C (1652° F). If the firing temperature is raised above these temperatures, the finished bricks exhibit a lower expansion potential. Each additional 50° C (90° F) rise results in a marked drop in permanent expansion.

When firing temperature approached the level at which desirable low porosity (2 to 8 percent) is attained, the expansion curve for most clays flattened out. Variations of 50° to 100° C (90° to 180° F) then had little effect on expansion.

Results of the periodic measurements of the bricks collected in phase 1 of the study are shown in figure 3. Curves are given for the brick that expanded most (A), the one that expanded least (B), and the average for

the bricks tested (C). The brick represented by curve A had been fired about 70° C (125° F) lower than the normal firing temperature. Most of the bricks tested had expansion curves much like that of brick B but showed slightly greater expansion.

EFFECTS OF EXPOSURE

Comparison of the expansion patterns of the bricks stored in a controlled atmosphere with those exposed to outdoor weather revealed that the latter expanded considerably more. As shown in figure 4, the difference was most evident during the first six months of the test, after which the rate of expansion for both groups was about the same.

The bricks stored outdoors were subjected to more severe conditions than would exist for bricks in an outdoor wall because they were exposed on 5 sides instead of one and their expansion was not inhibited by pressure such as a wall would provide. Bricks in a structure probably would not expand much more than those kept in the controlled atmosphere.

PREVENTION OF STRUCTURAL DAMAGE

When architects and contractors are aware of the expansion potential of the bricks they are using, steps can be taken to compensate for expansion. These are especially important when light colored bricks are specified. During the past 20 years light shades of brick have become very popular. Although some clays are naturally light burning, some light shades are produced by firing at a temperature lower than is generally used for the clay being burned. Unfortunately, if the temperature is too low the bricks are too porous. Bricks with high porosity are, of course, highly expansible.

Hosking et al. (1959) suggested four means of preventing expansion damage in brick structures.

1. Use well fired bricks with low porosity.
2. Allow bricks to stand as long as possible after they leave the kiln.
3. Use mortar that is rich in lime rather than mortar with a high cement content. High-cement mortars can become rigid in a week and cannot provide a cushion for the expansion of the bricks. Lime-rich mortar has more plasticity and can take up the expansion.
4. Provide expansion joints at sufficiently frequent intervals in the construction.

CONCLUSIONS

Several conclusions can be drawn from the results of the various tests.

1. The maximum expansion of a brick depends to a great degree on the temperature at which it was fired. The temperature that produces maximum expansion after firing differs for each clay.
2. Reduction of the normal firing temperature even a few degrees to produce lighter shades of bricks could increase permanent expansion considerably.

3. If the firing temperature is increased 50° C (90° F) above the point that would produce maximum expansion, the amount of expansion decreases considerably and continues to decrease with every 50° C (90° F) rise in temperature.

4. Above the firing temperature at which the porosity of the bricks is reduced to the desired level (2 to 8 percent), an increase of a few degrees will not greatly affect expansion.

5. Well fired, hard bricks expand little, if any, after a few months, but bricks fired at below normal temperatures may expand for a period of years.

6. For the first six months, bricks exposed to weather expand more than identical bricks stored under cover, but the rate of expansion subsequently is the same for both groups.

7. If bricks fired at a temperature lower than that required to reduce porosity to the proper level are to be used, allowances for expansion should be made by architects and contractors when construction is planned.

8. Bricks fresh from the kiln expand most and should not be used in construction. The longer the bricks are left standing before being used the less expansion will occur in the wall.

9. Bricks made in Illinois appear in general to be comparatively stable and do not show excessive expansion.

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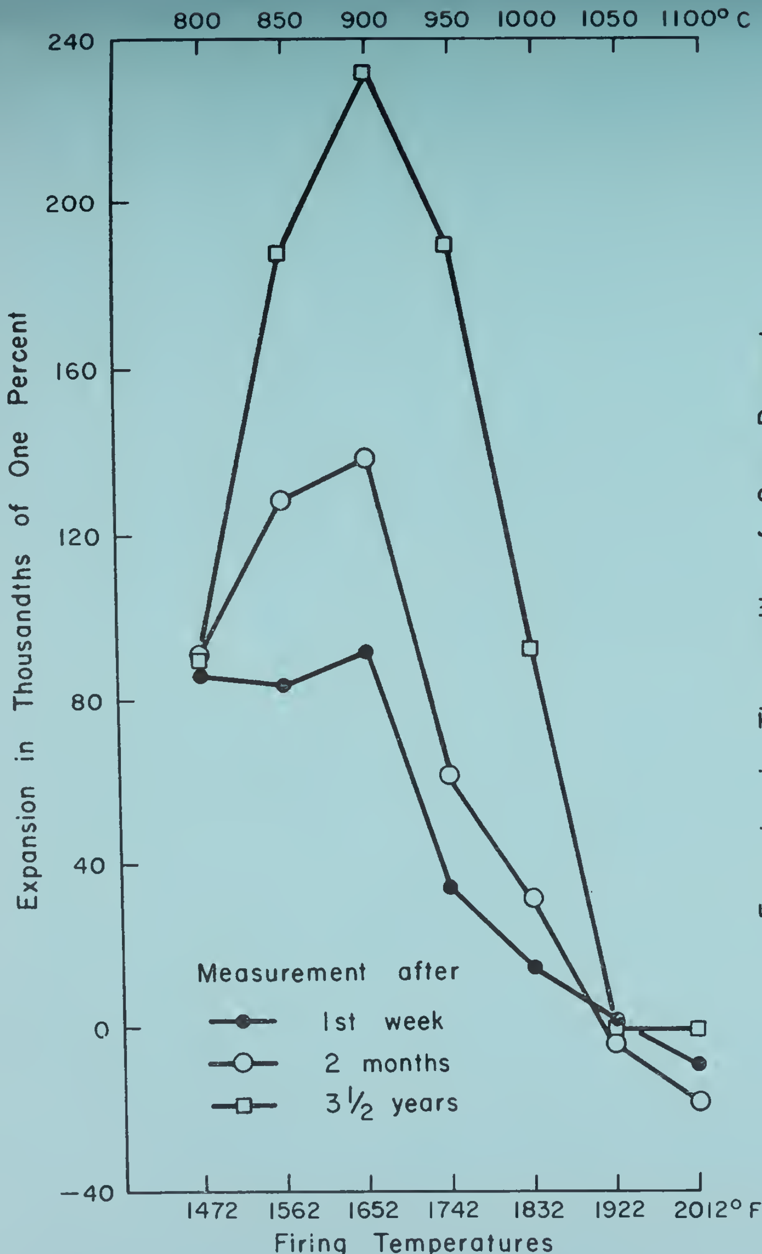

Fig. 1 — Illite from Fithian, Illinois

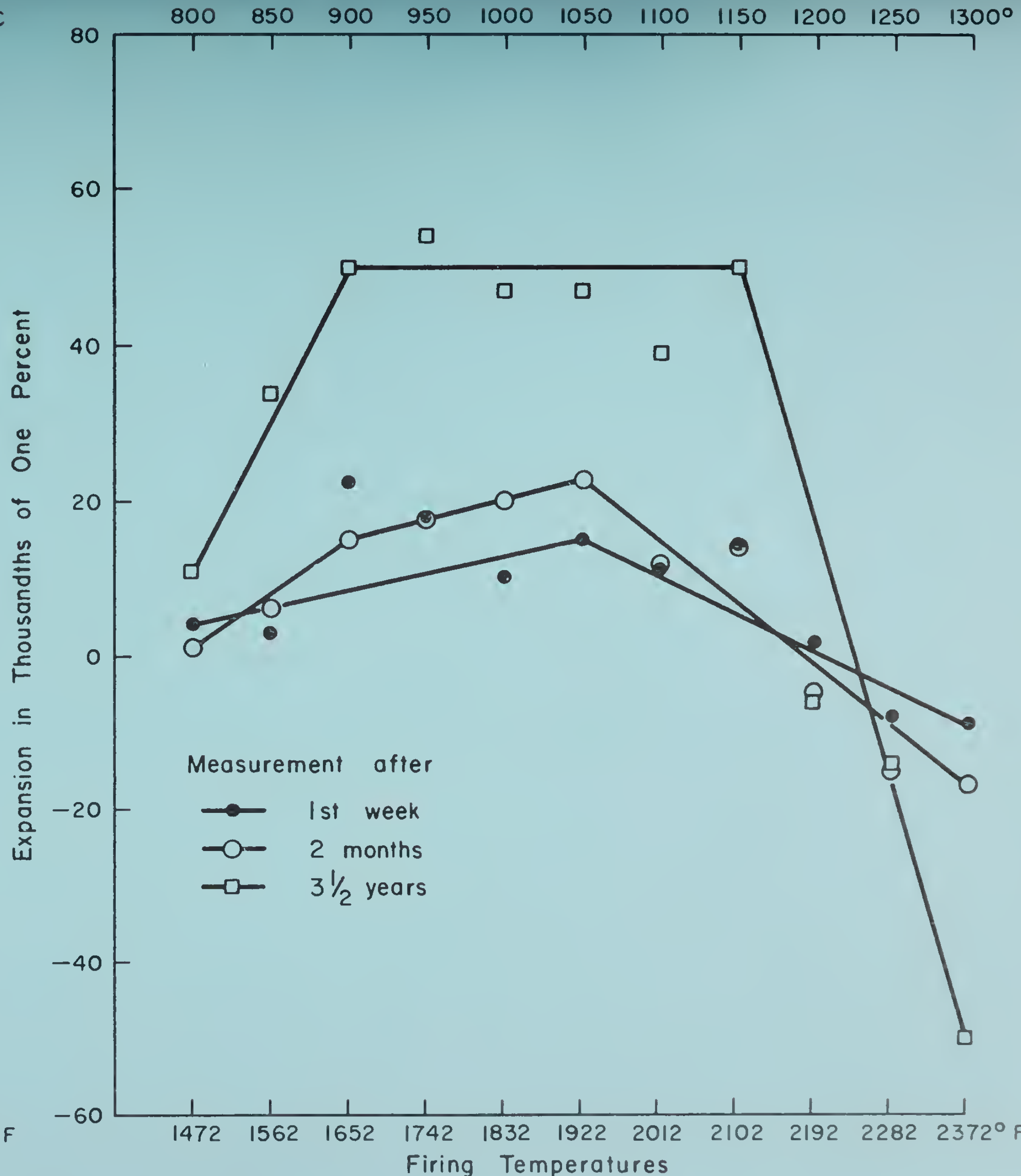

Fig. 2 — Kaolin from Anna, Illinois

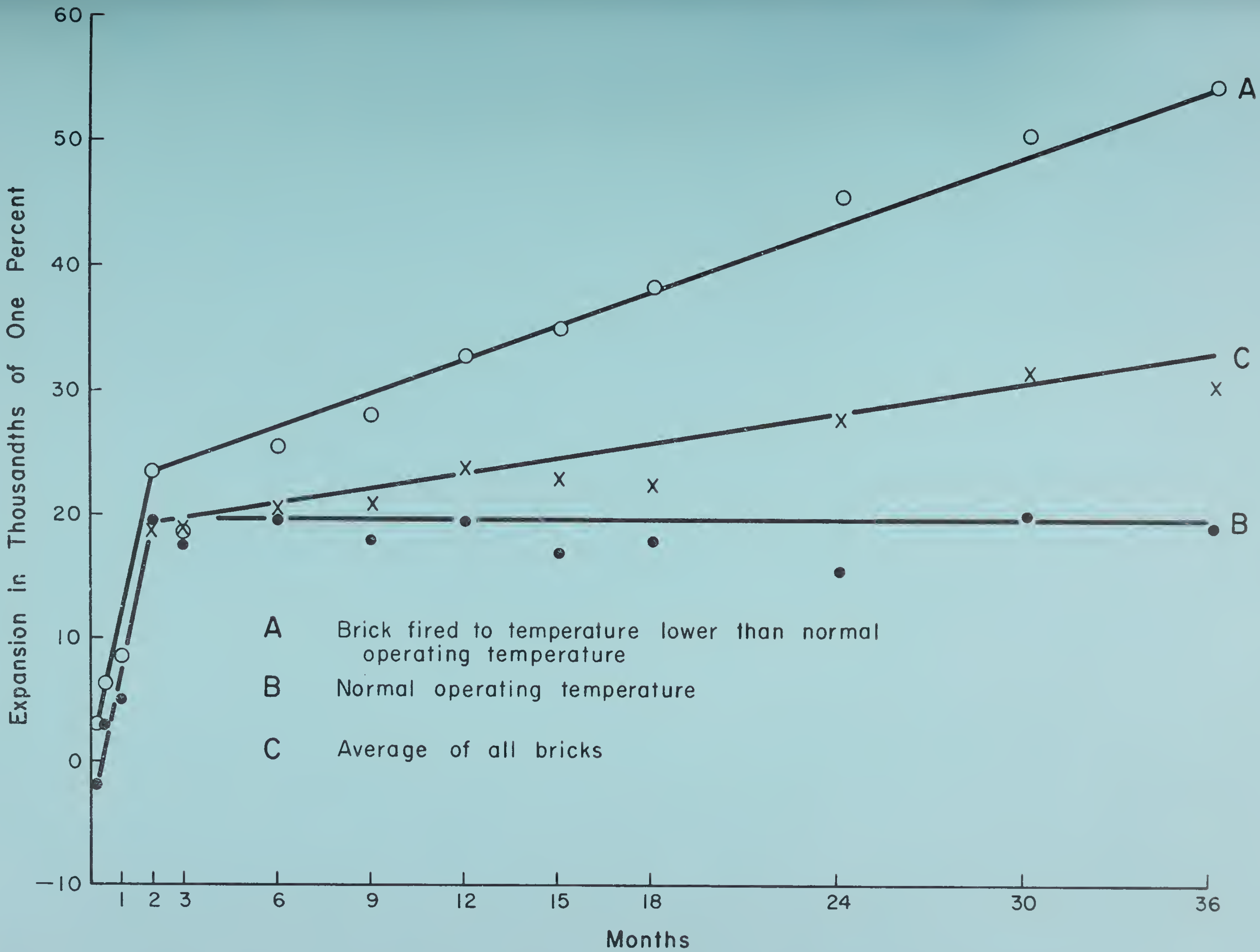

Fig. 3 — Expansion of bricks in controlled atmosphere

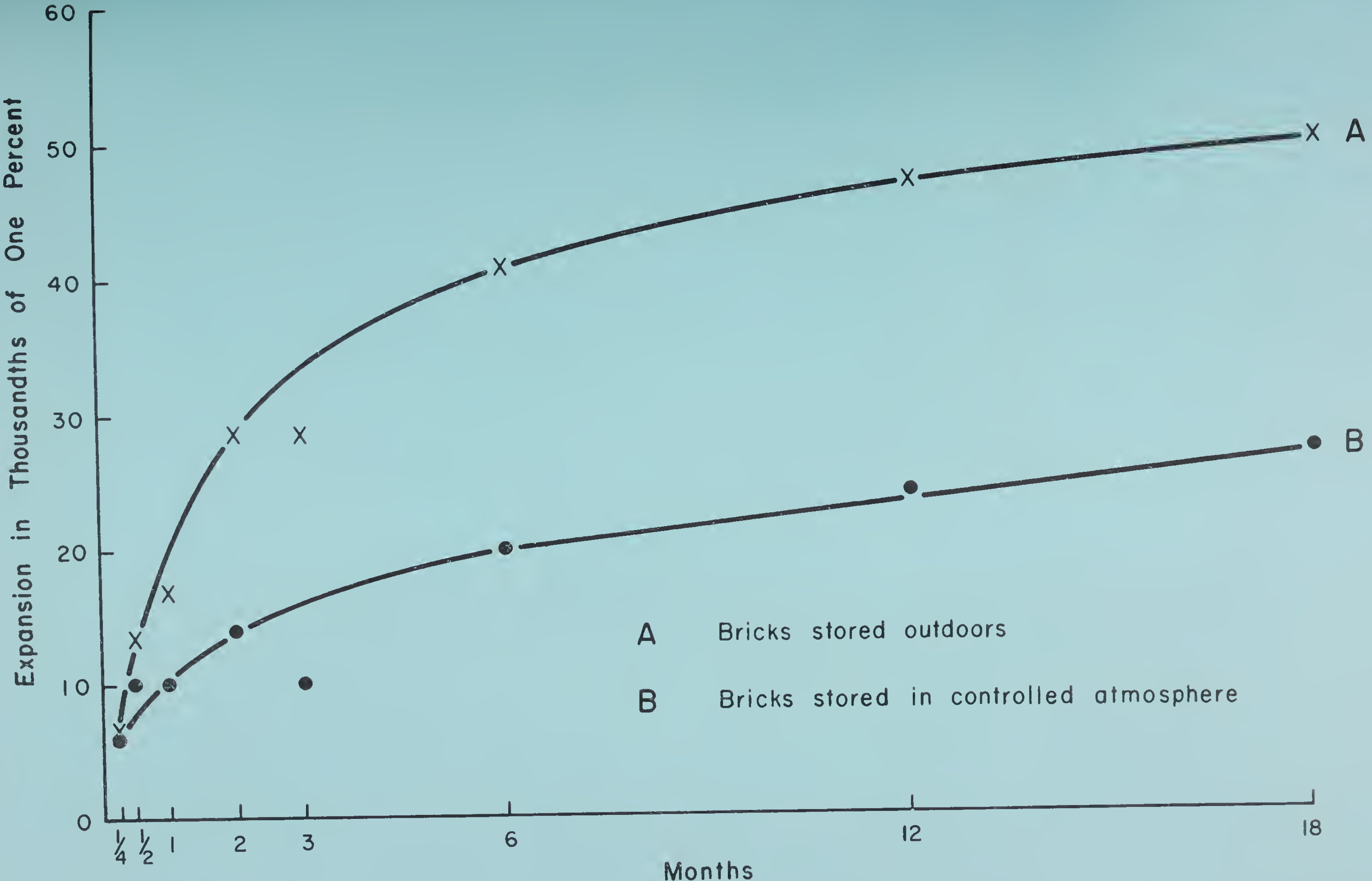

Fig. 4 — Expansion curves of bricks stored outdoors and bricks stored in controlled atmosphere