Variation in the volume of plaster during and after setting

Ito, S.; Teraoka, I.; Yoshihama, S.

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Title: Variation in the volume of plaster during and after setting.

Authors: Shuyo Ito, Ichiro Teraoka and Seiichiro Yoshihama, Research Laboratory of the Tokyo Shibaura Electric Company, Limited.

Reference: Gypsum, 1: 225-229, 1952.

Translator: K. Shimizu.

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PREFACE

Plaster continues to be an important building material in Canada and it is therefore the subject of some of the investigations now being carried out in the Building Materials Section of the Division of Building Research.

In the necessary and essential library research carried out in association with our laboratory work in connection with plaster problems, reference was found to this paper on the variation in the volume of plaster during and after setting from Japan. Study of the paper showed its value and its relevance to current experimental work being carried out by the Division and in other laboratories in North America.

The Division is therefore pleased to be able to include this translation in its series of Technical Translations, by permission of the author. The Division is grateful to Mr. K. Shimizu for preparing this translation.

Ottawa,
October 1956

R.F. Legget,
Director.

VARIATION IN THE VOLUME OF PLASTER DURING AND AFTER SETTING

1. Introduction

A part of this study has been published at the Fall Symposium of Plaster Research Group in Nagoya on October 25, 1951. The present paper deals with the results of further research. In the past only hardening and expansion of plaster due to hydration have been studied. However, contraction takes place at the beginning of hydration and expansion follows. Thus there is considerable difference in true expansion of plaster due to hydration between measurements made from the extreme of contraction and measurements made within the range of expansion. The authors have been able to measure contraction and expansion by means of a simple optical dilatometer which has been specially designed for the present work.

2. Materials Used

The following types of plaster were used:

(a) α and β type plaster made from crystals which were obtained from $CaSO_4$, a residue of the manufacture of hydrofluoric acid at the Kawaguchi Factory of the Shibaura Electric Co.,

(b) Commercial products by Yoshino Plaster Manufactures, Ltd. Two products were used (both β-type).

3. Equipment

The equipment was designed to measure thermal contraction and expansion. This can be used to measure expansion and contraction in plaster due to hydration. The use of this instrument enabled the authors to discover that regular contraction takes place before expansion which has been the sole subject of research in the past.

Main components of the equipment are shown schematically in Figure 1. It consists of a heater (not used in the present work), a quartz glass dilatometer (need not be quartz glass in the present work), a scale and a telescope. The main components of the dilatometer consist of test-material receiving stand and push bar both made of quartz glass. The bar is placed on rollers and pressed lightly by two rubber bands. The push bar is extremely light and moves sideways to the right and left. This movement turns the rollers and a mirror attached to a roller. The mirror is placed at the centre of the curved scale and reflects the graduations on the scale. The graduation is observed through a telescope. In this way both contraction and expansion can be accurately measured. When the plaster which is to be tested is placed between the receiving stand and the push bar, the change in the volume of plaster is immediately transformed into the rotation of the mirror. Thus by this equipment it is possible to observe continuously the contraction in volume of plaster before setting and the expansion after setting.

4. Results

The following experiments were conducted:

(i) when the amount of mixing water is changed;

(ii) when salts are added.

The results of experiments are shown below. Fig. 2 shows the change in volume of commercially available Y- and S-plaster with standard amount of mixing water (see editor's note).*

	Max. Cont.%	Max. Exp.%	Total Exp.%	Max. Temp.
Y-plaster	-0.015	+0.102 (90 min.)	0.117	30°C. (45 min.)
S-plaster	-0.010	+0.175 (90 min.)	0.185	36°C. (28 min.)

Fig. 3 shows the change in volume of α- and β-type plaster of Shibaura due to hydration with the change in the amount of mixing water added.

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*See footnote on page 4.

The following shows the change in volume:
(a) of α type plaster with standard water mix (see editor's note)* of 28% when 31%, 35% and 40% of water was added.

Water %	Max. Cont. %	Max. Exp. %	Total Exp. %
31	-0.022	+0.250	0.272
35	-0.010	+0.197	0.207
40	-0.038	+0.125	0.163

(Room temp. 26.5°C.)

(b) of α type plaster with standard water mix (see editor's note)* of 30%, when 40%, 50% and 60% of water was added.

Water %	Max. Cont. %	Max. Exp. %	Total Exp. %	Room Temp.
40	-0.105	+0.700 (145 min.)	0.805	11.5°C.
50	-0.147	+0.403 (90 min.)	0.550	11.5°C.
60	-0.015	+0.355 (75 min.)	0.370	12.8°C.

At 5%** there is an extraordinarily large contraction; however, there is a decrease in total expansion with increase in water.

Fig. 3 (c) shows the change in volume of β-type plaster with standard water mix (see editor's note)* of 50% with change in amount of water.

Water %	Max. Cont. %	Max. Exp. %	Total Exp. %
45	-0.025	+0.337	0.362
50	-0.062	+0.212	0.274
60	-0.036	+0.112	0.148
70	-0.035	+0.060	0.095
80	-0.012	+0.045	0.057

(Average Room Temp. 12.2°C.)

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*Editor's note:- The phrase "standard amount of mixing water" and "standard water mix" would appear to be equivalent to the phrase "standard consistency".

**Apparently a typographical error for 50%.

Figure 4 shows the change in volume with the change in water of (B) and (C) type of Yoshino Plaster Manufactures, Ltd.
(a) Change in the volume of β-type plaster (B) with the standard water mix (see editor's note)* of 45.8% when amount of water is changed.

Water %	Max. Cont. %	Max. Exp. %	Total Exp. %	Room Temp.
55	-0.027	+0.215	0.242	12.8°C.
60	-0.020	+0.115	0.135	14.0°C.
65	-0.007	+0.128	0.135	13.7°C.

The result shows that measured from the initial position, the expansion does not decrease in the order of increasing amount of water.

(b) Shows the change in volume of β-type plaster (C) with the standard water mix (see editor's note)* of 48.5% when the amount of water is changed.

Water %	Max. Cont. %	Max. Exp. %	Total Exp. %	Room Temp.
55	-0.125	+0.202	0.327	17.5°C.
60	-0.007	+0.215	0.222	15.4°C.
65	-0.005	+0.162	0.167	16.3°C.

The result, as in (a), shows that the expansion measured from the initial position does not decrease with the increase in the amount of water.

Fig. 5 (a) shows the change in volume of Shibaura α-type plaster with sodium citrate added; 30% water, 0.01 and 0.03% of sodium citrate was used.

Sodium citrate %	Max. Cont.%	Max. Exp.% (80 min.)	Total Exp.%	Room Temp.
0.01	-0.025	+0.275	0.300	20.0°C.
0.03	-0.014	+0.241	0.255	21.0°C.

*See footnote on page 4.

Fig. 5 (b) shows the change in volume due to hydration of Shibaura α-type plaster with 50% water and 1% sodium citrate.

Fig. 6 shows the change in volume due to hydration of Shibaura α-type plaster with sodium alginate added. It is seen that in all cases there is lengthening in the "apparent completion" time.

Water %	Ratio of Mix Sodium alginate to plaster	Max. Cont.%	Max. Exp.%	Total Exp.%
60	5 : 95	-0.095	+0.64	0.735
70	10 : 90	-0.177	+0.622	0.799

5. Analysis

By means of a newly designed dilatometer the authors measured the change in volume of plaster at the time of setting. They discovered that the volume contracts during the setting process and were able to measure the expansion in volume after setting. The review of the present work shows that the experiments can be summarized roughly by such a curve as shown in Fig. 7. Hydration in plaster is a reaction in which crystalline gypsum is evolved and heat is generated as shown in the following equation:

$$CaSO_4 \cdot 1/2H_2O + 1\tfrac{1}{2}H_2O = CaSO_4 \cdot 2H_2O + X \text{ cal.}$$

In this reaction, plaster dissolves at first, and gypsum crystallizes from the supersaturated solution; heat is generated followed by the development of crystals and expansion proceeds rapidly. It appears that after the crystals are fully developed, contraction in volume due to the drying of solid matter takes place.

Diagrammatically:

(i) O → A: Momentary contraction to A is observed. It appears as if plaster is mostly in solution during this period and tension predominates.

(ii) A → B: This also takes place in a short interval of time. Dissolution is rapidly taking place; heat is also generated.

(iii) B → C: Crystallization of small crystals of $CaSO_4 \cdot 2H_2O$ gradually takes place and heat is generated in greater quantity. At C the crystallization ceases. It appears as if this is the point of "apparent completion".

(iv) C → D: Short stationary state.

(v) D → E → F: Development of crystals takes place rapidly; volume expands rapidly with the generation of heat. Heat reaches a maximum in the neighbourhood of E. The temperature gradually declines, but expansion continues and at F its rate begins to decline. D → E the curve is concave up and E → F it is convex.

(vi) F → G → H: From F the curve, whose gradient was low, rises a little, and reaches its maximum at H.

(vii) H → I: Expansion stays at a constant value for a while then slow contraction takes place.

Naturally the shape of the curve depends on the properties of the plaster; further, depending on the condition under which the plaster was poured, there are cases where A → B can hardly be recognized; still in other cases, C and D coincide. Further examination of the diagram suggests to the authors the possibility that certain explanations can be made with regard to the start of setting, apparent completion, and completion of setting, i.e., point B indicates the beginning, and point C "apparent completion". Further, if the completion is indicated by the highest point on the thermometer, it must lie somewhere in the neighbourhood of E, the point of inflection. If the completion is to be taken as true expansion, point H must be taken as the completion of setting. Secondly, it is seen from the results of the present experiments that the increase in the amount of water results generally in the decrease in total expansion (Fig. 8) - this cannot be found from the consideration of contraction (-) and expansion (+) separately. It can only be known from the sum of absolute values (total expansion). Further, it was found that the presence of organic salts has considerable effect on the change in volume.

6. Conclusion

The authors were able to study the change in volume of plaster due to hydration by means of the optical telescope and using small quantity of test material. Our investigation is undoubtedly incomplete; however, we feel that our investigation gave us some insight into the problem. Further studies are underway on the effect of such factors as heat and strength, and others on the amount of water added and on the change in volume.

The authors wish to thank the Yoshino Plaster Manufactures, Ltd. for supplying them with test materials.

References

(a) Louis Chassevent. Variation in the volume of plaster during and after setting. Rev. matériaux construction et trav. publ., Ed. C., No. 407, 276-72, 1949; No. 408, 304-308, 1949. (C.A. 44: 299, 1950).

(b) Louis Chassevent. Matériaux construction et trav. publ., Ed. C., No. 405, 188-94. (C.A. 44; 1244, 1950).

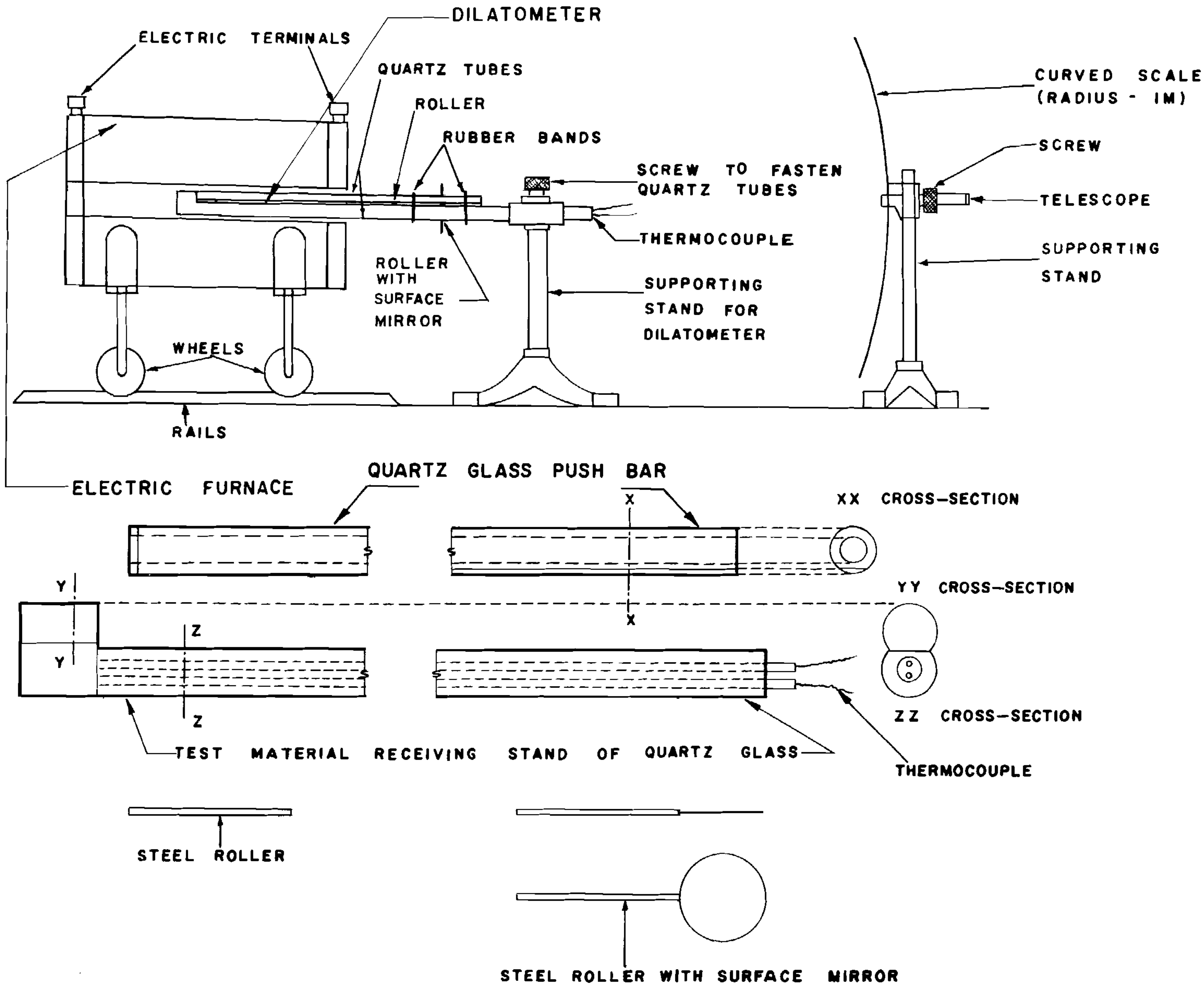
DILATOMETER
ELECTRIC TERMINALS
QUARTZ TUBES
ROLLER
RUBBER BANDS
SCREW TO FASTEN QUARTZ TUBES
THERMOCOUPLE
CURVED SCALE (RADIUS - IM)
SCREW
TELESCOPE
SUPPORTING STAND
ROLLER WITH SURFACE MIRROR
SUPPORTING STAND FOR DILATOMETER
WHEELS
RAILS
ELECTRIC FURNACE
QUARTZ GLASS PUSH BAR
XX CROSS-SECTION
YY CROSS-SECTION
ZZ CROSS-SECTION
X
Y
Z
TEST MATERIAL RECEIVING STAND OF QUARTZ GLASS
THERMOCOUPLE
STEEL ROLLER
STEEL ROLLER WITH SURFACE MIRROR

FIGURE I

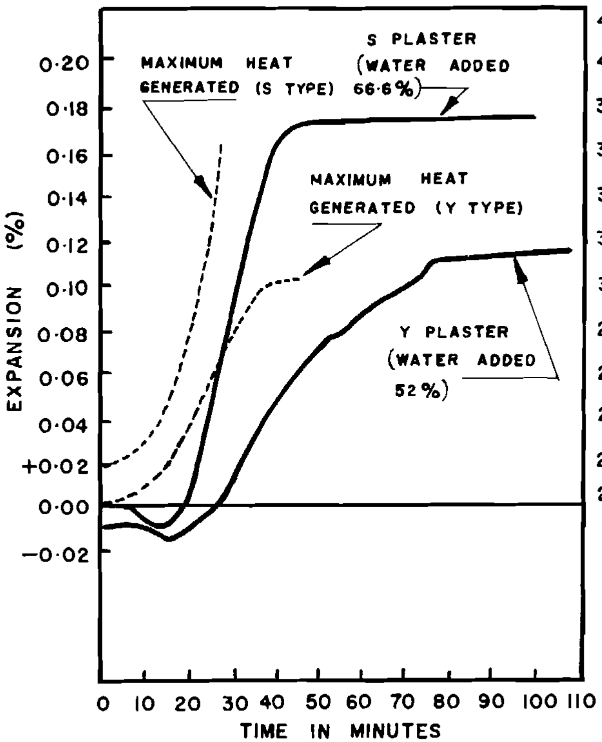

FIGURE 2

CHANGE IN VOLUME OF COMMERCIAL PLASTER DUE TO HYDRATION WITH CHANGE IN AMOUNT OF WATER ADDED

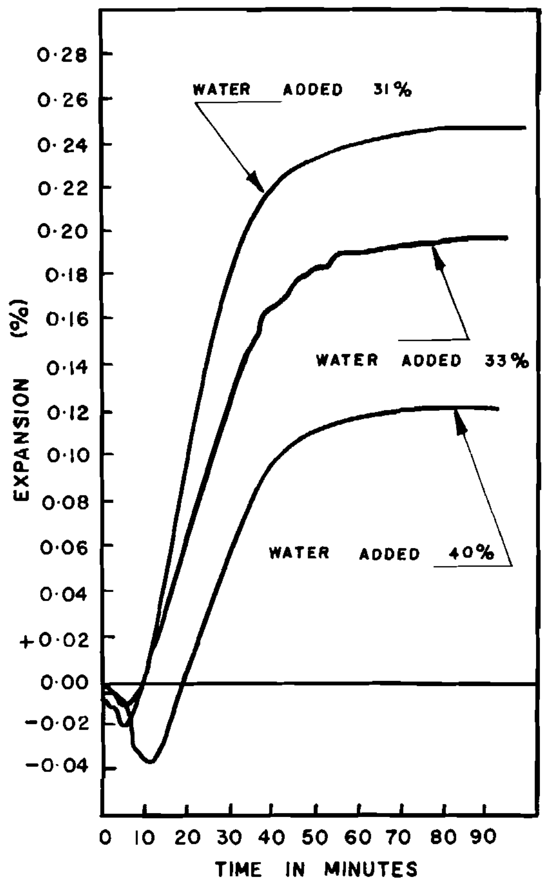

FIGURE 3a

CHANGE IN VOLUME OF SHIBAURA α — TYPE PLASTER WITH CHANGE IN THE AMOUNT OF WATER ADDED (STANDARD WATER MIX OF α- TYPE PLASTER 28%)

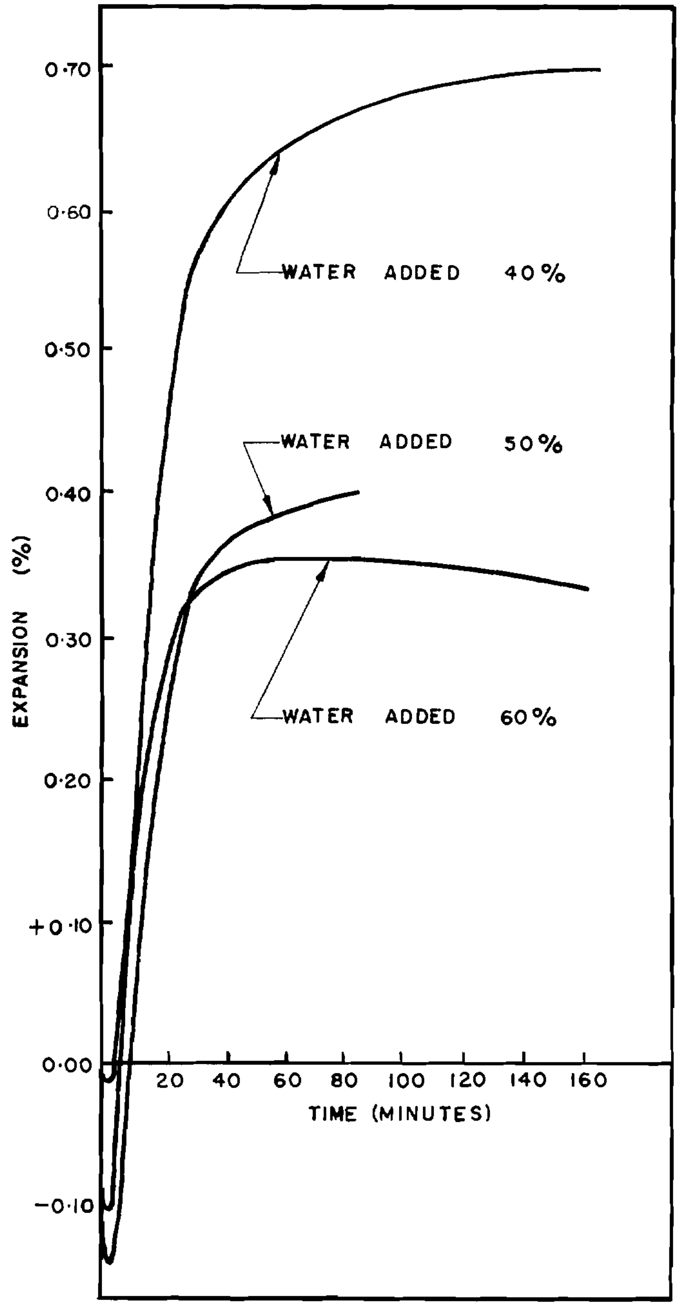

FIGURE 3(b)

CHANGE IN VOLUME OF SHIBAURA α - TYPE PLASTER WITH CHANGE IN THE AMOUNT OF WATER ADDED, (STANDARD WATER MIX OF α - TYPE PLASTER - 30%)

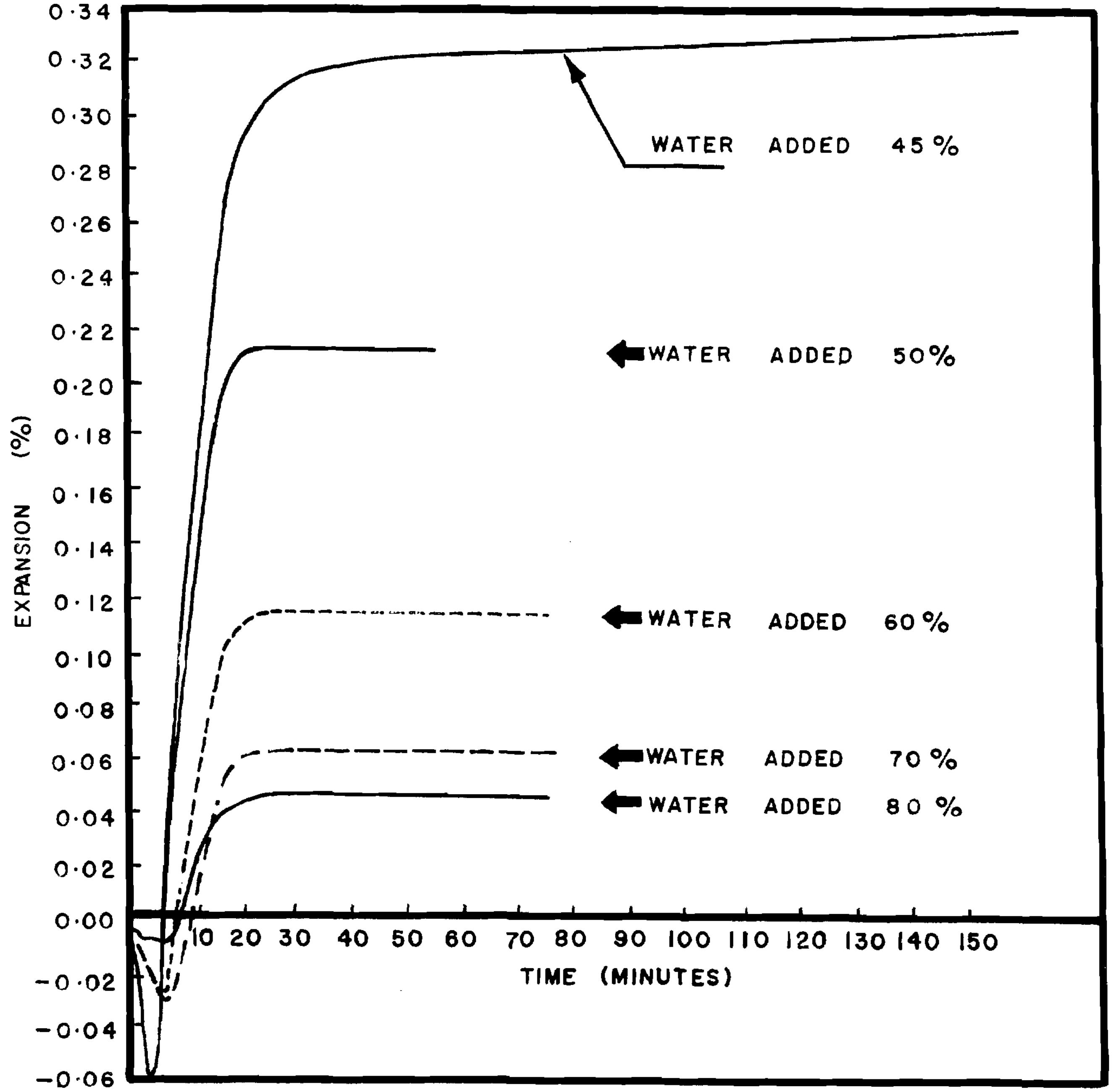

FIGURE 3(c)

CHANGE IN VOLUME OF β - TYPE PLASTER OF STANDARD WATER MIX 50% WITH CHANGE IN THE AMOUNT OF WATER ADDED

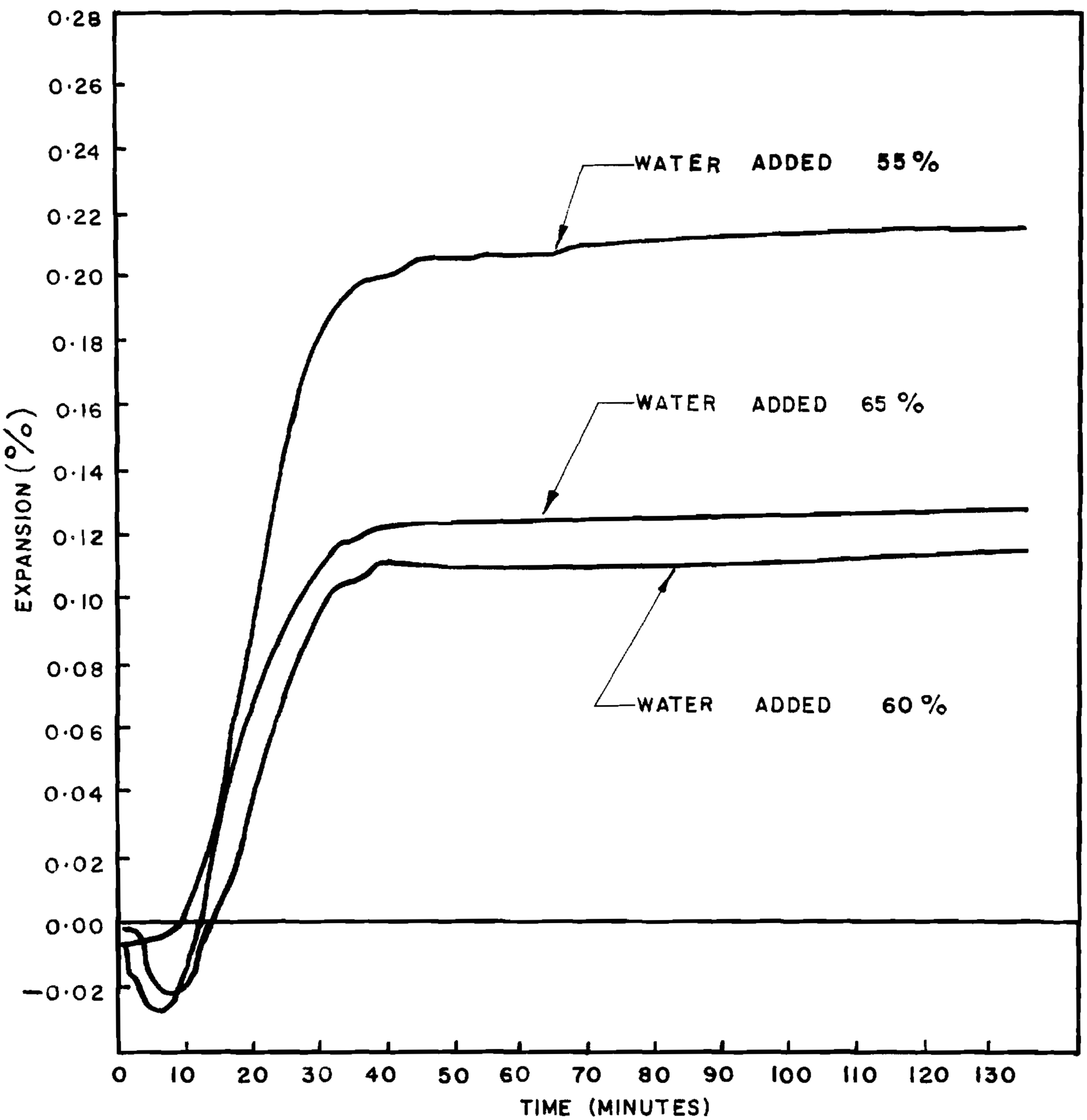

FIGURE 4(a)

CHANGE IN VOLUME OF β-TYPE PLASTER OF STANDARD WATER MIX OF 45·8% WITH CHANGE IN THE AMOUNT OF WATER ADDED

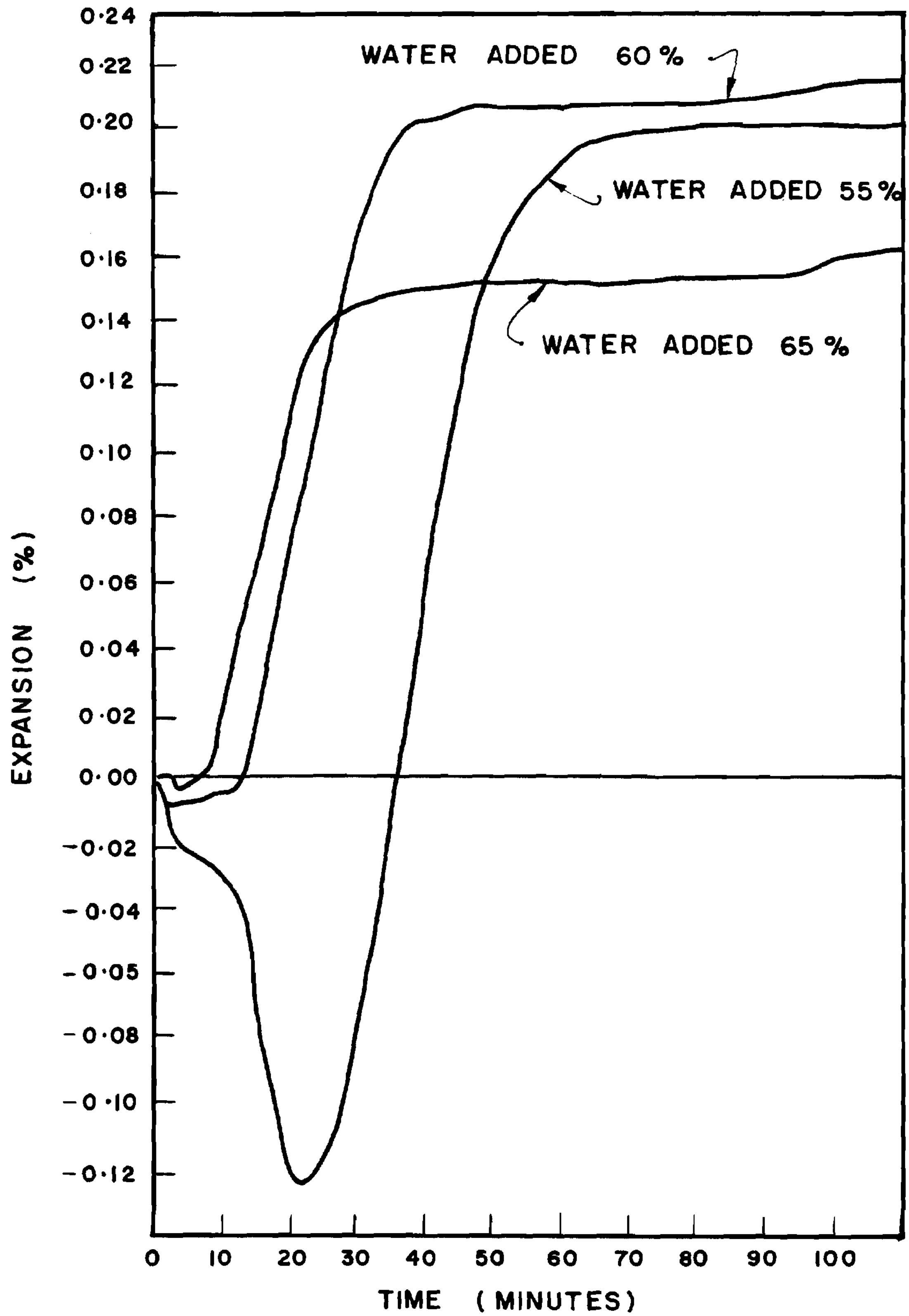
WATER ADDED 60 %
WATER ADDED 55 %
WATER ADDED 65 %
0·24
0·22
0·20
0·18
0·16
0·14
0·12
0·10
0·08
0·06
0·04
0·02
0·00
-0·02
-0·04
-0·05
-0·08
-0·10
-0·12
EXPANSION (%)
0
10
20
30
40
50
60
70
80
90
100
TIME (MINUTES)

FIGURE 4 (b)

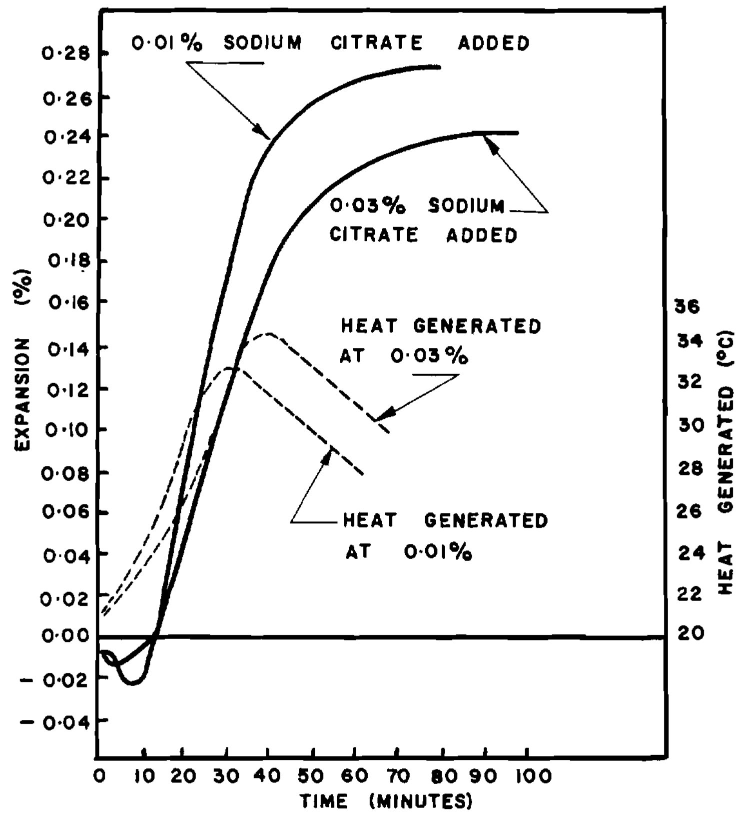

FIGURE 5(a)

CHANGE IN VOLUME OF SHIBAURA α - TYPE PLASTER DUE TO HYDRATION WHEN SODIUM CITRATE IS ADDED

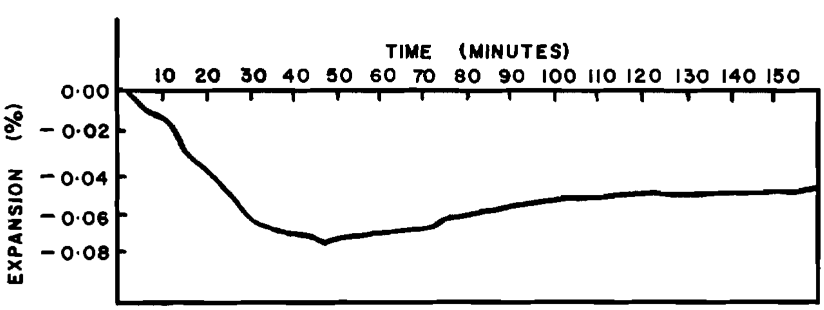

FIGURE 5(b)

CHANGE IN VOLUME OF SHIBAURA α -TYPE PLASTER WITH AN ADDITION OF 1% SODIUM CITRATE AND 50% WATER

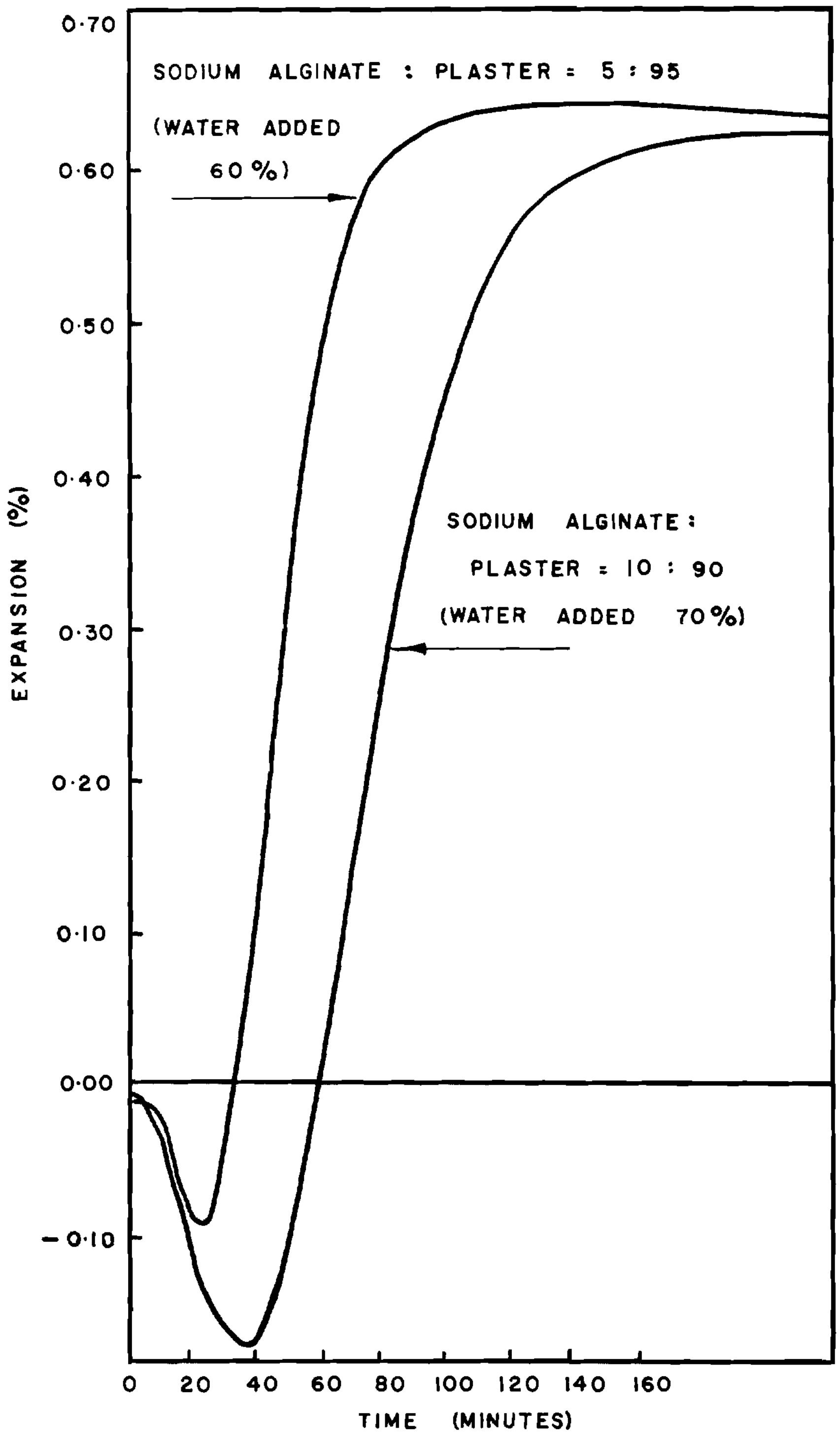

FIGURE 6

CHANGE IN VOLUME OF SHIBAURA α – TYPE PLASTER DUE TO HYDRATION WHEN SODIUM ALGINATE IS ADDED

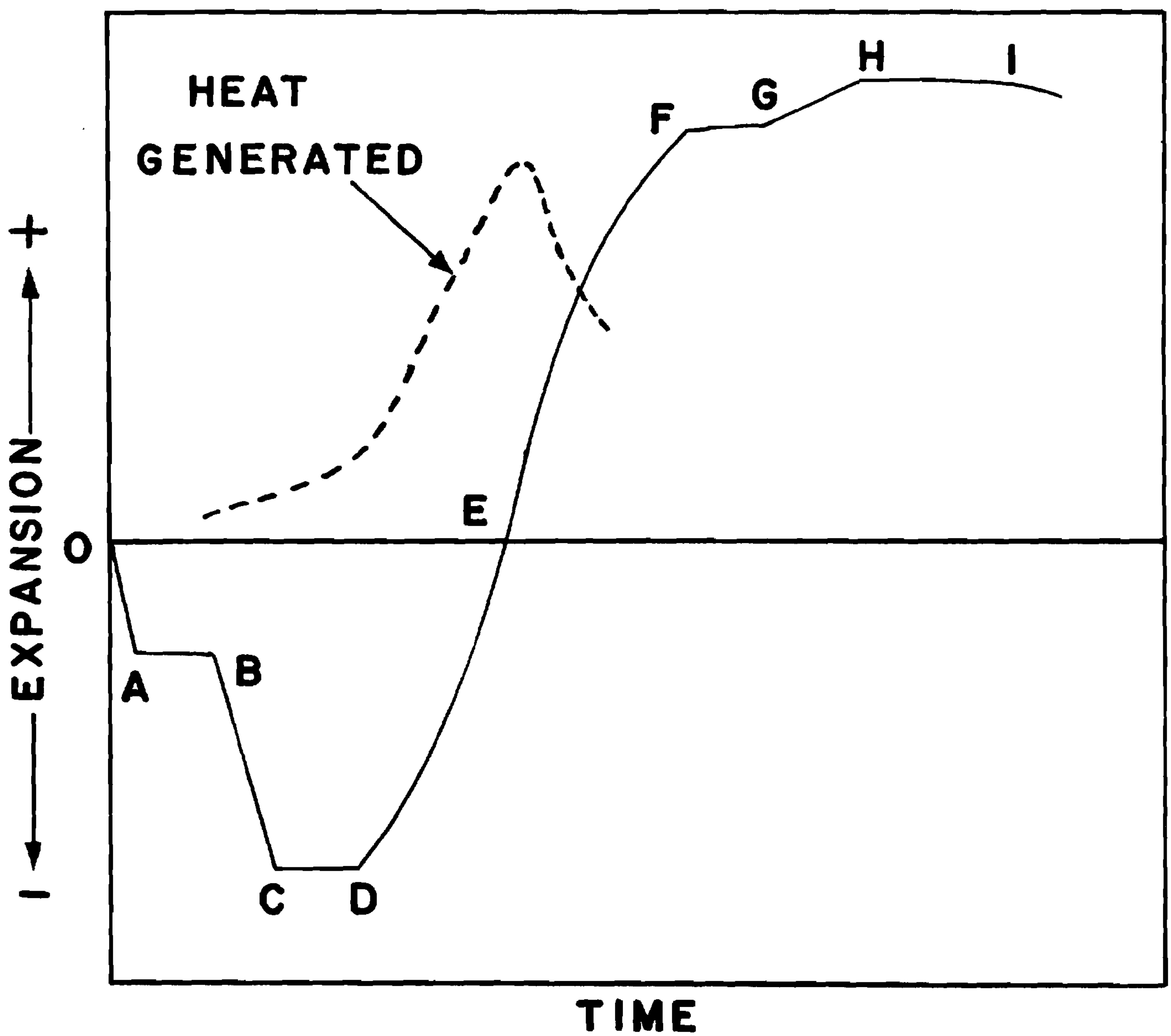

FIGURE 7

CHANGE IN VOLUME OF PLASTER DUE TO HYDRATION

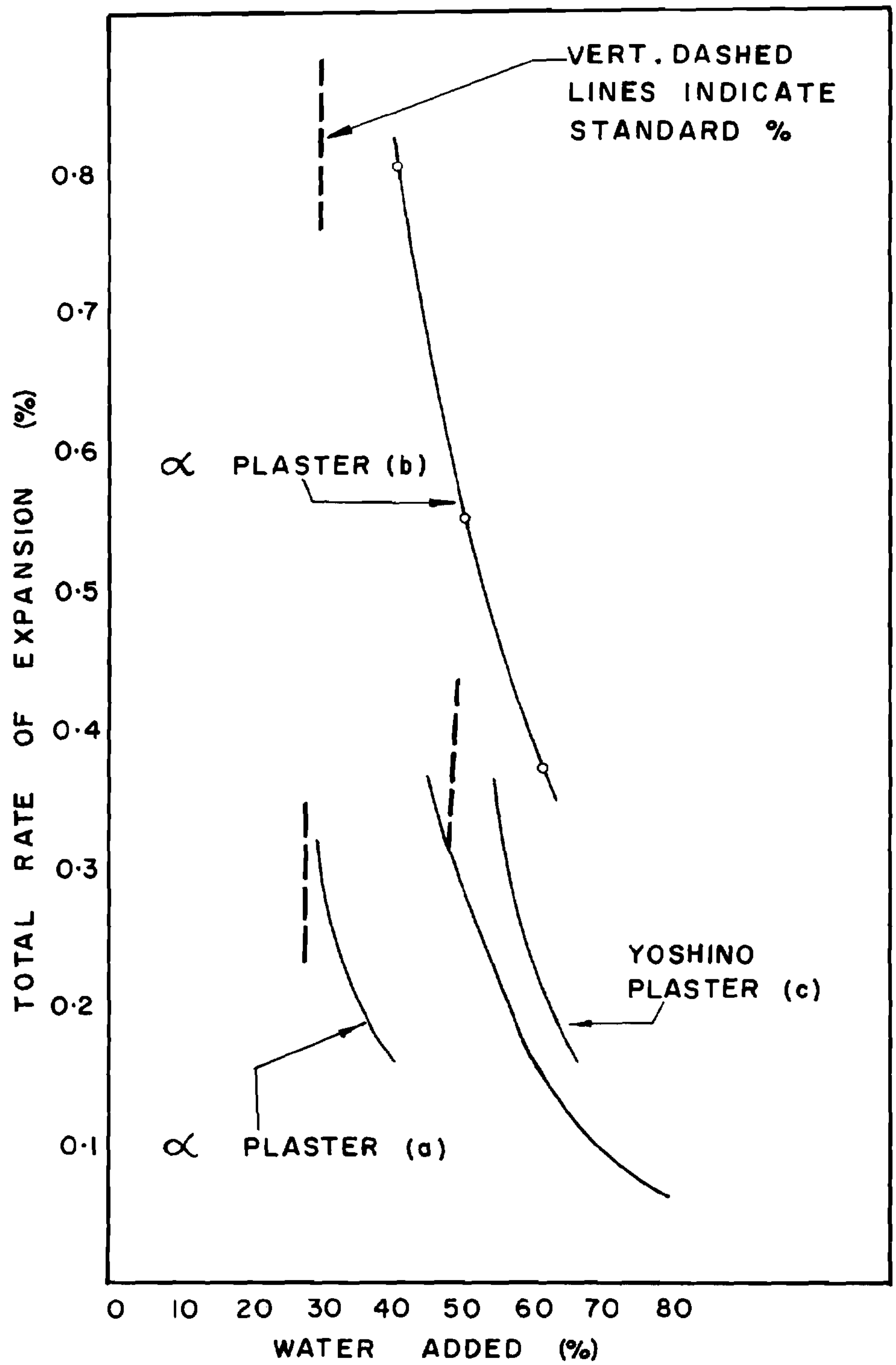

FIGURE 8

TOTAL EXPANSION AND CHANGE IN THE AMOUNT OF WATER ADDED