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RESEARCH REPORT ON
A STUDY OF
NON-MODULAR MASONRY CONSTRUCTION

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RESEARCH REPORT ON
ABSTRACT
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 conducted by

SMALL HOMES COUNCIL

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An analysis of the time-study data taken during the construction period indicates that the masons' time can be reduced approximately 10 per cent through the use of modular materials. Furthermore, an examination of the brick-work indicates that an improvement in workmanship is possible through the use of modular materials. This improvement in workmanship is obtained through the regularity achieved by the use of modular materials.

By

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 and
 Gerhard C. Rettberg

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In 1947, the Small Homes Council made a detailed study and comparison of construction methods used in residential building. Included in this study was an analysis of three houses in which modular brick were used in the exterior cavity-type masonry wall. No comparison has been available between the data so obtained and the time required to construct the same wall using non-modular materials.

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CONTENTS

I. FOREWORD AND PURPOSE

Page

ABSTRACT 2

I. FOREWORD AND PURPOSE 4

II. DESCRIPTION OF THE INVESTIGATION 5

A. The House 5

B. The Contractors 5

C. Recording Methods 6

D. The Site 7

E. The Weather 7

F. The Workmen 8

III. RESULTS AND OBSERVATIONS 8

A. Time Data 8

B. Construction 12

C. Brick Size 13

D. Rate of Work 14

E. Cut Brick 14

F. Engineered Drawings 14

IV. SUMMARY AND RECOMMENDATIONS 15

Addenda

- 1 Masonry Walls
- 2 Masonry Walls - Detailed Breakdown

Drawings

- 1 Tracing of Photograph, Non-modular Masonry House; 1949
- 2 Tracing of Photograph, Modular Masonry House, 1947

(1) See Small Homes Council Technical Report, 22.18 "Research Report on Construction Methods."

RESEARCH REPORT ON
A STUDY OF NON-MODULAR MASONRY CONSTRUCTION

I. FOREWORD AND PURPOSE

In 1947, three masonry houses were built under the supervision of the Small Homes Council as part of a study on construction methods.¹ A detailed time study was made for each trade, including the masons, but the data so obtained was limited to the three houses in which a modular-sized brick (nominal 8-inch length, laid three courses to 8 inches) was used. No similar data has been available for non-modular masonry construction.

The purpose of the current investigation was to collect data on the construction of a non-modular masonry wall; to record and analyze all phases of the construction; and to compare current data with that previously obtained so that conclusions could be drawn regarding the advantages or disadvantages which might be attributed to the use of modular-sized masonry units.

This report covers the construction of one house similar in every respect to the three built two years ago except that a "standard" or non-modular brick was used in the exterior wall. This investigation and the construction of the house, on which the study was made, were sponsored by the Structural Clay Products Institute. The research was done by the Small Homes Council of the University of Illinois.

(1) See Small Homes Council Technical Report, E2.1R "Research Report on Construction Methods."

The contract for II. DESCRIPTION OF THE INVESTIGATION

A. The House

The house used for this investigation was the "L"-shaped, industry-engineered house designed by A. Gordon Lorimer, architect for the Producers' Council and the National Retail Lumber Dealers Association. It was built from the same general drawings used for the masonry houses in the 1947 test. These drawings were based on the assumption that modular materials would be used throughout and called for a 10-inch cavity-type wall for the exterior of the house -- outside wythe of brick, 2-inch air space, and inner wythe of concrete masonry units. Due to the 10-inch thickness, the exterior face of the wall did not fall on a grid line.

At the time the current project was started, it was felt that since non-modular brick was to be used, there would be no advantage in changing the dimensions of the house itself -- no one dimension being any more non-modular than another. Similarly, the steel sash and the back-up materials were the same (modular) size as had been used previously. The dimensional coordination of all other materials thus became unimportant since the brick themselves were non-modular. Consequently, both the house and the openings in the wall are exactly the same size as in the original or modular structures.

B. The Contractors

In order to avoid introducing new variables, it was decided to use the same masonry subcontractor who was employed on the 1947 project. He submitted two proposals: one a lump sum figure for labor and material; the other, a cost-plus percentage with the added note that if there was to be a time study or "other interference" with the work, he would take the job only on the cost-plus figure.

D. The contract for the general work was awarded to Leroy V. James on a cost plus fixed-fee basis, and he was instructed to employ the masonry contractor chosen by the Small Homes Council.

The masonry contractor was merely told that the Council was going to build another house similar to those built in 1947 "only this time a 'standard' size brick was to be used." He was given no special instructions or directions. It was requested that he have, if possible, the same crew as was used on the 1947 job.

C. Recording Methods

Three time-study workers, University of Illinois architectural students, were employed for a two-weeks' period. Their work during the two days prior to the actual start of construction on the masonry wall was to become familiar with the time-study techniques of the Small Homes Council and with the house itself.

During the construction period, the time-study workers were on the site continuously, recording the operations of the masonry crew. They used the same forms as those for the 1947 tests. For a description of the techniques and methods, procedures and forms used in the time study, see the Small Homes Council technical report, "Research Report on Construction Methods," Index No.

E2.JR.

After the completion of the construction work, these same three men returned to the Small Homes Council Laboratory where they assisted in the tabulation and assembly of the time-study data. The only variations between the current study and those made previously were:

- (1) A change in the name of one element, "Cut and Chip" replaced "Mark and Saw" (previously chosen to cover all trades).
- (2) The combining of a number of minor elements into one general heading, "Miscellaneous."

D. The Site

The research house was built in western Champaign² in a new subdivision which is completely surrounded by a good residential area. The streets are paved (concrete). Sanitary sewer, storm sewer, water, gas and electric power are available. The lot, 70' x 132', is high and well-drained.

Immediately after the excavation was finished, the sewer and water lines were installed. By the time the foundation, floor joist and subfloor were finished, the preliminary rough grading on the site was completed. Before the masons returned to start the exterior wall, all backfill had been placed; rough grading had been completed, and the area surrounding the building was level, smooth and firm. The grade approximated finished grade, 8 inches below the lowest course of brick. The working conditions were excellent -- trucks delivering material could back in from the pavement, and the site was unobstructed except for two piles of surplus dirt which were some distance away from the house itself.

This situation, by far the best of any of the houses, was a contrast to the site conditions which prevailed in the 1947 test. There, the streets were unpaved and often impassable. Lots were low, with the result that materials had to be carried up long ramps to reach the first-floor level. The first courses of brick (those from the foundation to the floor line) were very difficult to lay since they could not be reached from the ground.

E. The Weather

There had been no rain in Champaign for some time prior to the construction of the exterior wall. The ground therefore was dry and the footing was good.

(2) 1201 West Clark Street

The weather was sunny and warm. This condition prevailed for the first three days of work. On the first two days of the following week, there were showers which interrupted the masons' work. Official temperature reports taken at 1 p.m. on each of the workdays follow:

Wednesday, June 8, 1949	-	72 degrees
Thursday, June 9, 1949	-	76 degrees
Friday, June 10, 1949	-	71 degrees
Monday, June 13, 1949	-	79 degrees
Tuesday, June 14, 1949	-	77 degrees
Wednesday, June 15, 1949	-	71 degrees

F. The Workmen

An entirely different attitude prevailed among the workmen than that noted during the 1947 project. The general attitude was one of desire to do work as rapidly as possible. All of the men employed were receiving regular union wages, the prevailing wage scale being \$3.25 an hour. In the 1947 project, all of the men employed were receiving foreman's wages and most of the contractors were offering pay considerably above scale, including room and board allowances for out-of-town workers. At the present time, there is no local shortage of skilled labor, and workmen in all classifications are available.

III. RESULTS AND OBSERVATIONS

A. Time Data

Page 1 of the addenda shows the time-study data for the current investigation in comparison with similar data for masonry houses No. 1, No. 2 and No. 3, taken in the 1947 project. The total hours (skilled plus unskilled) for the non-modular masonry house are slightly less than the similar total for any one of the three houses built in 1947.

Before any analysis is attempted, all unskilled man-hours must be removed from the total because the number of brick laid per day does not reflect the

number of unskilled man-hours, except in extreme cases such as if there were no unskilled labor or if there were so many men on the job that they caused interference. The amount of unskilled labor often depends on the number of men the contractor assigns to the job. The variation between the number of man-hours of unskilled labor recorded in the three houses during the 1947 test is due to this fact.

The first masonry house built in 1947 was laid up during extreme hot weather by masons who were not particularly familiar with cavity-wall construction. The cavity-wall of the third masonry house was started during cold weather and construction was delayed for many weeks due to a severe winter; the house was completed in the early spring. Weather conditions during construction of the No. 2 masonry house are more nearly comparable with those existing this year. Because of these extremes in weather, it seems desirable to compare the current non-modular structure with the second masonry house. Thus considering only the skilled labor, it is evident that the number of man-hours for the non-modular house is comparable with that for the second masonry house built in 1947.

Addenda No. 2 shows the time elements for the non-modular house and for the No. 2 masonry house of 1947 subdivided to indicate the skilled and unskilled labor. The original data collected during 1947 was examined and the division of time on the Masonry No. 2 house was taken from that data. This data was not published in this form in the original report on construction methods.

A comparison of the total amount of skilled labor required to construct the houses indicates that while nearly the same amount of time (115.210 hours versus 117.003 hours) was spent on both houses, the advantage in gross skilled labor is in favor of the non-modular house. A comparison of gross time, how-

ever, does not reflect the actual difficulties involved in using non-modular masonry units. The time data for the various elements shows that site conditions, as well as a different attitude on the part of the workmen, changed the distribution of time within the gross totals mentioned above. Similarly, other elements do not directly reflect time variation resulting from a small change in brick size. For example:

Element No. 1, "Tools"

1.806 man-hours in 1949 versus 4.198 on the modular structure in 1947 (No. 2 masonry house). This indicates the generally more alert attitude on the part of the workmen.

Element No. 2, "Materials"

6.654 in 1949 versus 5.764 on modular house (No. 2) in 1947. This element is mainly for unskilled labor. The small variation of approximately one hour may be due to superior stock piling by the mason tender.

Element No. 3, "Supervise"

4.726 man-hours versus 6.743 required on the No. 2 masonry house in 1947. This reduction in supervision time was due to increased familiarity with cavity-type wall construction.

Elements 6 to 12, inclusive

Minor elements, including idle time and temporary construction, none of which are affected by a slight change in brick size or in the coordination between materials.

Element No. 13, "Lay Block and Brick"

59.646 man-hours on the non-modular house in 1949 and 66.998 man-hours on the second masonry house in 1947. The actual operation of laying block and brick is a mechanical procedure, or habit pattern, which the mason has

(3) See Appendix No. 13, "Research Report on Construction Methods," Index No. 13.18.

practiced so long that a minor variation in the size of the brick unit in no way influences the process of spreading mortar or shoving the brick into place. This is shown most clearly in a comparison between the second and the third masonry houses built in 1947. Here approximately thirty less man-hours of masons' time was required on the No. 3 house, yet there was less than one man-hour difference between the two houses in the element, "Lay Block and Brick."³ This element therefore is not included as one which reflects a change in the brick size although it might be assumed at first to be important in any comparison between modular and non-modular products.

Only three elements can be said to directly reflect the change in brick size. These are:

Elements:	1949		1947	
	Skilled	Unskilled	Skilled	Unskilled
4. Measure, Level, Plumb	13.327	.004	10.711	-
5. Cut and Chip	2.282	-	1.438	-
14. Plaster and Tool Joint	<u>14.435</u>	-	<u>6.979</u>	-
	30.044	.004	19.128	-

Element No. 4, "Measure, Level, Plumb" - includes the time spent laying out the brick coursing around the building and in establishing a story pole for vertical brick coursing.

Element No. 5, "Cut and Chip" - gives the result of non-modular units and their lack of coordination with both the building size and other parts of the building, such as doors and windows.

Element No. 14, "Plaster and Tool Joint" - shows most clearly the point at which the masons had the greatest difficulty due to the constant changing

(3) See Appendix No. 13, "Research Report on Construction Methods," Index No. E2.1R.

in spacing, and to the squeezing, or adjusting, of the brick joints in order to avoid cutting brick.

The total time for skilled labor for the three elements listed above is 30.044 man-hours for the non-modular house and 19.128 for the modular structure. In other words, it required 10.916 additional hours to measure, level, plumb, cut, chip, and tool the joints on the non-modular house. This is 9 per cent of the total skilled labor required to lay the entire wall. This represents an actual difference in the time required to lay modular and non-modular brick.

B. Construction

In the non-modular house, both the bed joints and head joints vary considerably in thickness. Head joints at various parts of the building vary from less than $1/8$ " to almost $3/4$ ". Similarly, bed joints vary from $3/8$ " to almost $3/4$ ". Cut brick appears in all of the small piers between windows. At these points, the brickwork is somewhat more even than it is in the larger panels where the mason exercised every known trick in order to avoid cutting brick. The bricks, which were cut, vary in length and are not regular in their location. Vertically, adjustments in height at the windows were made by placing additional wood fillers over the wood surround to take up the difference, or the slope of the brick sill was reduced to a point where moisture troubles may quite possibly be experienced.

An examination of the modular houses built two years ago shows that while head joints vary, the variation is due to a normal difference in the length of the bricks as they come from the kiln; however, a regularity is maintained because each brick is centered within two grid lines. The drawings on pages 3 and 4 of the addenda are made from photographs taken at the two houses used for comparison in this report. The drawing of the non-modular masonry house is not

exaggerated, and it does not indicate all of the difficulties of poor workmanship which were encountered. The drawing is of the same area shown in the official photographs where grid lines were simulated by a frame in which strings were fastened at 4-inch intervals.

C. Brick Size

Because of the slightly larger size of the non-modular brick (averaging almost 7-7/8 inches in length and laid three courses to 8.163 inches), 3-1/2 per cent less brick was used in the non-modular house. This reduction is due mainly to the elimination of one course completely around the building.

In the height of 8'-0" from the top of the foundation wall to the underside of the lintel on the windows, there were 36 courses of modular brick in the 1947 house. The same space (reduced to 7'-11-1/4") in the non-modular house required only 35 courses of brick. Horizontally around the building, there was little variation between the two houses in the number of brick required. For example, the front bedroom wall of the modular brick house required 25 stretchers and 2 cut brick (the cut brick resulted from the 10-inch cavity wall's forcing the outside wythe off the grid). In the non-modular brick house, this same space was filled with 25 stretchers and 2 headers. Alternate courses for the modular brick were 24 stretchers, 2 cut brick and 2 headers; and for the non-modular, 26 stretchers.

The end of the living room wing and the end of the bedroom wing have the same outside dimension of 17'-8". In the modular house, the brick detail for these two locations was naturally identical. In the 1949 experiment, no layout of brickwork had been made and the foreman spaced the brick in each piece of the wall as a separate problem. The result was that in one wall --- the bedroom --- there were 25 stretchers plus 2 headers; in the living room, 25 stretchers

plus 1 header. Alternate courses were 26 stretchers versus 25 stretchers plus 1 header. It is this irregularity which produced the great variation in head joints and resulted in the poor appearance of the masonry wall.

D. Rate of Work

The rate at which the men worked is indicated by the following table based on the first two days of work when no piers or windows were involved.

	<u>First Day</u>	<u>Second Day</u>
Brick laid - per day, per mason	414	476
Block laid - per day, per mason (4 x 8 x 16) (in addition to brick)	90	61
Total number brick -	5,763 (wall only)	
Total number block -	983 (wall only)	

E. Cut Brick

In the modular house, the number of cut brick and their location could be predicted. The masons knew where they were to be used and how many were required; and, on some of the houses, they would start the morning by cutting brick while the laborers were mixing mortar. In this way, they built up a stock pile of cut brick which was used throughout the day; therefore, the operation of cutting did not interfere with the regular rhythm of laying brick. On the non-modular house, there was no way in which the mason could foresee the number or location of the cut brick.

F. Engineered Drawings

The completeness of the engineered drawings for the modular house has a definite influence on the character and quality of the brickwork. When using modular material, it is possible to predict the coursing on the drafting board with accuracy and economy of time. In the non-modular structure, each run of

wall was solved in the field for brick layout, without regard to what had been done on other wall areas (see note regarding number of bricks per course above).

IV. SUMMARY AND RECOMMENDATIONS

It is difficult to draw conclusions based on experiments conducted in only one house, especially when site conditions and labor relations are so different than those encountered in the experiment of 1947.

Gross time was reduced primarily because every possible precaution was taken to provide ideal working conditions for the workmen building the non-modular test structure. In spite of this general reduction in totals, the elements which reflect a change in brick size show an increase in man-hours. This increase can be traced to the lack of coordination between the brick and the other parts of the structure, and between the brick and the over-all dimensions of the structure.

The irregularity in the wall resulting from this lack of dimensional coordination can best be described as poor workmanship.

Based on this limited test, use of modular masonry units is recommended because:

1. They reduce the number of man-hours of labor approximately 9 per cent even in a simple structure.
2. They standardize construction with a resulting increase in quality of workmanship at no additional expenditure of labor.
3. They make possible the use of engineered drawings which, in turn, assist in producing savings based on the standardization of all materials.

(*) Corrected figures based on audit made since publication of official report.

MASONRY WALLS

	1949 Non-Mod.	M-1	1947 M-2*	M-3
<u>Total Hours</u>	187.374	271.700	197.094	274.004
Skilled	115.210	140.312	117.003	148.180
Unskilled	72.164	131.388	80.091	125.824

Elements:

1. Tools	1.806	13.257	11.288	3.477
2. Materials	36.741	62.851	44.343	47.031
3. Supervise	4.778	11.436	6.817	17.807
4. Measure, Level, Plumb	13.331	15.342	10.711	12.030
5. Cut and Chip	2.282	2.230	1.438	3.584
6. Assist	3.122	3.448	.549	5.018
7. Error	.140	.087	.493	.371
8. Idle Personal	2.064	7.411	3.794	3.383
9. Idle Avoidable	14.674	17.167	5.371	4.673
10. Idle Unavoidable	7.956	23.591	8.231	11.003
11. Temporary Construction	2.351	11.712	7.064	7.269
12. Miscellaneous	11.086	10.785	5.694	22.503
13. Lay Block and Brick	59.646	57.507	66.998	68.292
14. Plaster and Tool Joint	14.435	13.726	6.979	6.548
15. Mix and Temper	12.353	17.981	16.108	13.244
16. Set Ties or Clips	.443	3.169	1.216	.873
17. On the Job	.166	-	-	46.898

<u>Total Time</u>	187.374	271.700	197.094	274.004
Productive Time	103.496	113.609	95.625	176.152
Preparation Time	59.044	109.835	83.580	78.422
Non-productive Time	24.834	48.256	17.889	19.430

(*) Corrected figures based on audit made since publication of official report.

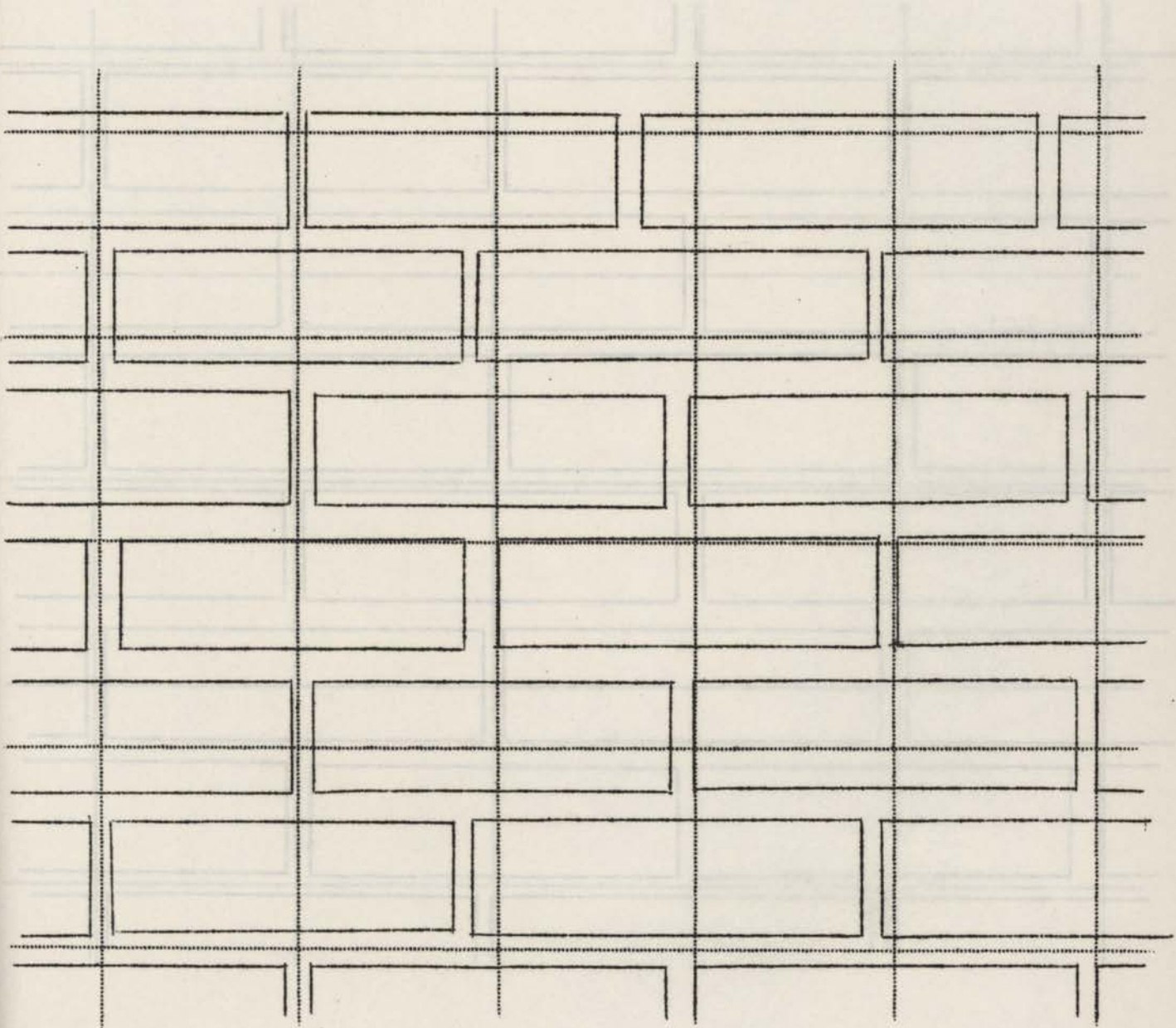
FRAMES OF PHOTOGRAPH, NON-MODULAR MASONRY BRICK, 1949

MASONRY WALLS - DETAILED BREAKDOWN

<u>Elements:</u>	1949 Non-Modular		1947 Masonry #2*	
	<u>Skilled</u>	<u>Unskilled</u>	<u>Skilled</u>	<u>Unskilled</u>
1. Tools	1.806	-	4.198	7.090
2. Materials	6.654	30.087	5.764	38.579
3. Supervise	4.726	.052	6.743	.074
4. Measure, Level, Plumb	13.327	.004	10.711	-
5. Cut and Chip	2.282	-	1.438	-
6. Assist	2.284	.838	.017	.532
7. Error	.082	.058	.493	-
8. Idle Personal	1.284	.780	1.384	2.410
9. Idle Avoidable	.053	14.621	1.406	3.965
10. Idle Unavoidable	5.586	2.370	3.002	5.229
11. Temporary Construction	1.347	1.004	2.419	4.645
12. Miscellaneous	1.031	10.055	1.933	3.761
13. Lay Block and Brick	59.646	-	66.998	-
14. Plaster and Tool Joint	14.435	-	6.979	-
15. Mix and Temper	.058	12.295	2.302	13.806
16. Set Ties or Clips	.443	-	1.216	-
17. On the Job	.166	-	-	-
	<u>115.210</u>	<u>72.164</u>	<u>117.003</u>	<u>80.091</u>

(*) Corrected figures based on audit made since publication of official report.

TRACING OF PHOTOGRAPH, NON-MODULAR MASONRY HOUSE, 1949



TRACING OF PHOTOGRAPH, MODULAR MASONRY HOUSE, 1947

