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Higher Productivity with Modular Units

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This article describes work studies carried out on small panels built under controlled conditions for ascertaining the relative output of a brick layer when using traditional and modular bricks/blocks. The measures necessary to standardise the method for comparative evaluation are discussed followed by a discussion of the results of observations and comparative economics of the three forms of construction. The study lays the groundwork for a more extensive investigation (now in progress), which is expected to establish norms for working with modular units.

Introduction

Burnt clay bricks have been used as a building material since time immemorial. In spite of the advent of concrete and other materials, bricks still form the main walling material for most of the buildings in this country. Equally significant is the fact that walling constitutes over one-fifth of the building cost and that any appreciable economy achieved by varying the size of the brick or method of laying can have substantial effect on the total cost of the building. The optimum size of brick has, therefore, been a subject of considerable interest and controversy. Since the Indian Standards Institution has now come out firmly in favour of the 10 cm. module and recommended a nominal size 20 cm.×10 cm.×10 cm. (approximately 8″×4″×4″) brick, productivity studies on modular bricks are of considerable interest to the industry. This paper describes the pilot studies carried out on small panels constructed with the traditional bricks, modular bricks and modular blocks at this Institute.

Basis of Comparison

It was obvious that the studies should aim at obtaining a comparison of output between traditional and modular bricks. Since modular bricks were not available in the market, it was decided to manufacture the bricks at the Institute kiln. Based on certain earlier studies carried out by Sarvasri L. C. Jain and J. S. Sharma on large size bricks with deep frog showing that a brick of a size larger than 8″×8″×4″ was both difficult to mould and handle, it was decided to also include a modular block of the size of 8″×8″×4″ (double of modular brick) in the study.

Description of Materials Used

Traditional Bricks: Fig. 1 (a) :—The traditional bricks used in this part of the country (west of Uttar Pradesh) are of the nominal size 9″×$4\frac{1}{2}$″×3″ with a frog of $6\frac{3}{4}$ length×2 width×3/8″ depth. In actual practice the size varied greatly due to the indigenous methods of manufacture. Even though selected bricks were used in these studies, the size was found to vary from 9″×$9\frac{1}{2}$″ in length, 4=3/8″ to 4=5/8″ in breadth and $2\frac{3}{4}$″ to 3″ in height. The size of the frog did not show any significant variation.

Modular Bricks: Fig. 1 (b) :—These bricks, nominal size 8″×4″×4″, were manufactured at the Institute

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kiln. They varied from $7\frac{3}{4}''$ to $8''$ in length, $3=5/8''$ to $3-7/8''$ in breadth and height. The frog provided was $5''$ long $\times 1''$ wide $\times 2\frac{3}{4}''$ deep and did not show any significant variation.

Modular Blocks : Fig. 1 (c) :—These were of a nominal size of $8''\times 8''\times 4''$ with a frog $4\frac{3}{4}''\times 4\frac{3}{4}''\times 2\frac{1}{2}''$. They were also manufactured at the Institute kiln. The size varied from $7\frac{3}{4}''$ to $8''$ in length and breadth and from $3\frac{3}{4}''$ to $4''$ in height.

The physical characteristics of all the brick units are given in table I.

Table 1

Showing Characteristics of Brick Units

Sl. No.	Type of unit	Weight of unit in lbs.	Compressive strength of unit in lbs./sq. in.	% Water absorption by weight after 24 hrs. immersion	Remarks
1.	Traditional bricks	7	2120	13	Available from local market
2.	Modular bricks	5·5	1730	11	Manufactured at CBRI Kiln
3.	Modular bricks	12·25	1850	7·2	-do-

Mortar : The mortar used for the construction of panels was composed of 1 cement to 8 sand by volume. The volume of both the materials was properly controlled with suitable allowance for bulking of sand, and the consistency of mortar was controlled by adding a predetermined quantity of water. Since some variation in the time lag between the mixing and use of mortar could not be avoided, precautions were taken to supply mortar of such a consistency as to need no further addition of water or dry materials by the brick layer. The mortar was unloaded directly on the wall by the Mazdoor. (Fig. 2).

Method Standardisation

Preliminary studies indicated a great variation in the method of laying brick units, even when the same brick layer was working. Since these had a significant effect on output, it was necessary to eliminate these as far as possible. The observed method and steps taken to standardise the method for the purpose of this study are given in Appendix I.

Method of Construction of Panel

The first course was laid permanently on the floor to ensure that the length of panel remained unchanged throughout the trials. The brick layer started the laying of all the courses from his left towards his right. In every course, first the end bricks/blocks were laid by checking proper plumb and string. The mortar for placing the end units was taken by the brick layer from the mortar pan supplied at both the ends of the panel. Mortar for laying the remaining units was directly unloaded on the preceeding layer by a mazdoor. The brick layer spread the mortar for a length approximately equal to 4 bricks/2 blocks at a time. He then picked up bricks/blocks by his left/both hands respectively from the stack and laid it on the mortar bed in line with the string and pressed it in position by a hammer (Basuli). The traditional bricks were laid frog up while the modular bricks/blocks were laid frog down.

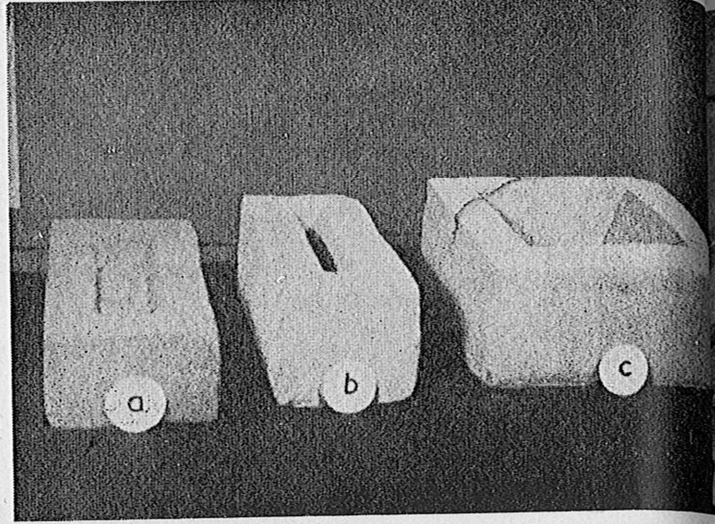


Fig. 1 (a) Traditional Brick (b) Modular Brick (c) Modular Block

Fig. 2 Wall panel with modular blocks under construction showing supply of mortar directly on the panel.

After laying 4 bricks/2 blocks the brick layer shifted his position and repeated these operations till he reached the other end of the course. The brick layer then laid the end brick/block for the next course in proper plumb and tied the string to the brick. After this he went back to the starting point and laid the end brick/block at that point and fixed the string in position. He then laid 4 bricks/2 blocks at a time as described above and finished the facing joints in the course below. The brick layer worked in the sitting position upto a height of about 16″ (5 courses in traditional bricks and 4 courses in modular bricks and blocks) and in the standing position from the height of 16″ onwards. The back joints

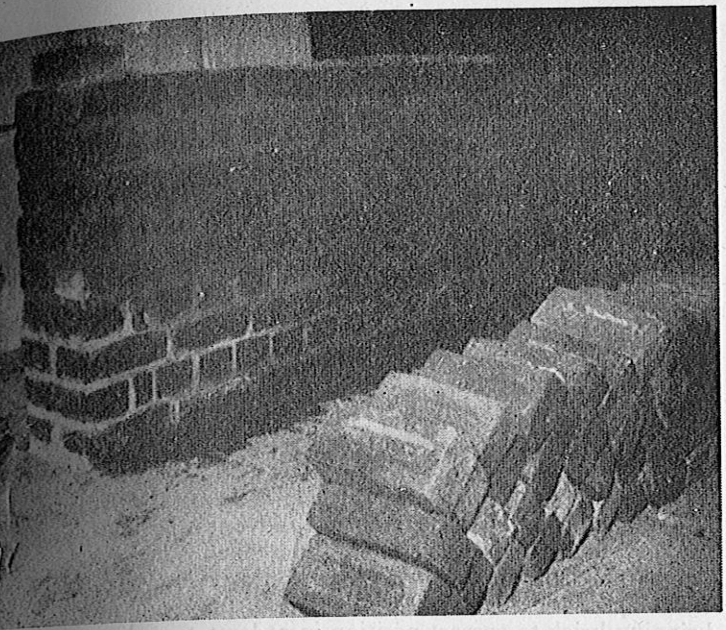


Fig. 3 Showing stacking arrangements of traditional bricks

were completed in one operation subsequent to reaching the full height of panel. The panels built with any particular brick were identical in all respect except that the sequence of laying header an dstretcher courses was alternated so as to detect the variation in time taken for laying due to change in sequence of header/stretcher courses.

Working Conditions

To avoid any significant effect of weather, all panels were constructed under cover. To eliminate any appreciable variation in output due to fatigue, the brick layer was required to work a fixed time period in the morning and afternoon every day during the period of study. Rest of the time, he assisted in getting the panel dismantled and cleaning the bricks/blocks free of mortar. The bricks/blocks were soaked in water and stacked ready for use.

Workmen

A brick layer of normal health and average skill was selected to construct all the panels under controlled conditions. The aim of the study was clearly explained to him. He was given time to fully understand and gain proficiency in the standardised method. He was provided with two mazdoors to supply mortar and bricks/blocks. These mazdoors were also trained to supply mortar directly on the wall panel and arrange bricks/blocks behind the brick layer in the prescribed manner (Fig. 3).

Tools

The brick layer utilised tools of conventional type while the mazdoors also made use of metal pans, spade and shovel as usual.

Size and Number of Wall Panels

Since the available quantity of modular bricks/blocks was limited, the size of panel was restricted to about 10 ft. × 4 ft. (giving a wall area of 40 sq. ft. approximately) and the thickness to that of one brick/block. The number of bricks/blocks utilised in each type of panel was kept the same. The number of panels was selected on the basis of available time and resources for the study and the feasibility of repeat uses for the bricks/blocks. A total of 30 panels were constructed, 10 numbers with each unit. Since the method of laying and working conditions were effectively controlled, it was anticipated that the number of observations taken would be adequate to give a confidence level of 95% with ± 5% of variation. A subsequent check indicated that this anticipation was fully justified (refer table No. 4).

Recording of Observations

Preliminary trials had indicated that laying of a single brick/block could not be taken as an element, because certain operations such as shifting the position, tools and spreading of mortar were carried out once during a cycle of 4 bricks/2 blocks. Since this also facilitated the task of the observer, without affecting the accuracy of the observations for purpose of comparative evaluation, a cycle of laying 4 bricks (traditional or modular) or 2 modular blocks was taken as an element, the break point occuring when the brick layer started spreading mortar for the next cycle of bricks. The time study observations were separately recorded for each course. In each course relating to traditional/modular bricks, the observations for laying end bricks (one brick in header courses and 2 bricks in stretcher courses) were separately noted to account for the difference in operations involved as well as stringing and corner plumbing. Similarly the observations for laying and blocks (half and full used in alternate courses) was separately recorded. The operations for finishing back joints were treated as a separate element for purpose of time study.

The results of time studies are given in Tables 2, 3, 4 and 5 as under:

Table 2

This shows the number of units/joints used in each type of panel, averages of cycle time for laying end and intermediate units and back jointing of the panel as well as total time taken for panel construction.

Table 3

This shows the average of elemental times for laying end and intermediate units separately for each course as related to its height from the floor and posture of brick layer.

Table 4

This shows number of observations actually taken/required for desired accuracy and the variation from the anticipated confidence level.

Table 5

This brings out the comparative output and economics of the three types of units.

Findings and Discussion

Table 2—Cycle Timings

Table 2 shows that, in the regular cycle, as well as at the ends, the least time is taken for laying the modular blocks and the maximum in case of traditional bricks. The time taken for modular bricks is somewhere around the mid range between modular blocks and traditional bricks. The reason for this difference in time of laying can be attributed to difference in size of the unit, which in turn affects the number of units to be handled and the quantity of mortar required for a given wall area. The relative outputs are no doubt influenced by the size of the panels studied and the conditions of working. For example, construction of these panel does not involve carriage and and lifting of units to appreciable heights or working on scaffolds. Both these factors would tend to increase the laying time for heavier units. The observed timings can, therefore, be regarded as indicating a comparative trend and more realistic values need to be the established by construction of full scale walls representing average conditions in practice.

Stretcher *Versus* Header Course in Regular Cycles

Table 2 also shows that, in the regular cycle, laying of stretcher courses takes more time than the header courses both for traditional and modular bricks. This difference is attributable to the need of applying mortar on the back side of the brick (away from the brick layer) laid in stretcher course. This operation (not necessary in header courses) involves holding the brick in left hand, while the mortar is applied with the right hand, and placing the brick in position followed by placing another stretcher alongwith the front stretcher to make up the thickness of the wall. Another contributory reason appears to be the need of bringing relatively longer side of the brick to string, in stretcher courses, than that in headers. Both these reasons result in the header courses being completed in lesser time than the stretcher courses. The latter reason also appears to be responsible for the modular bricks taking less time to lay than the traditional bricks both as stretcheres or headers. The relatively greater difference between timings for stretchers and headers, for modular bricks as compared to traditional bricks, appears to be due to the greater difference in the vertical area of brick over which the mortar has to be applied (64 sq. in. in modular bricks as compared to 54 sq. in. in traditional bricks). The extra time taken on this account is much more than that taken for spreading the mortar over a greater horizontal area in traditional bricks (324 sq. in. as against 256 sq. in. in modular bricks). The net result is a greater difference for modular bricks as compared to traditional bricks, thereby establishing that the output is likely to reduce for units having larger vertical sides.

Stretcher *Versus* Header-End Cycles

As compared to regular cycles, the end laying involves half the units in stretcher courses and one quarter of the units in header courses. The time taken is however much more because of the need for carrying out of extra operations of adjusting the string, plumbing and bringing brick to correct position in at least two directions. The laying of stretcher ends takes longer time than the header ends, but, unlike the regular cycles, stretcher ends involve laying of twice the units than that of header ends. Therefore the effective time taken per header end is proportionately greater than that per stretcher end. This is attributable to the need of greater care in checking the plumb of the header on its exposed side along the width of the wall which is longer than that in case of a stretcher. Thus even though, adjusting to the string takes relatively more time for stretcher than the header, this operation reduces the care necessary in checking the plumb at the exposed end for the stretcher, ultimately resulting in more time being taken for a header than a stretcher.

The relative difference in time of laying of stretcher *versus* header is 27,31,13 percent in case of traditional bricks, modular bricks, and modular blocks respectively. The greater difference in modular

Table 2

Sl. No.	Type of Unit	No. of units required in a panel of 10′×4′ size approx	Total area of the Panel built (SFT)	Average time for laying a cycle of 4 bricks/2 blocks (seconds)		Average time for laying corner units including plumbing & stringing (seconds)		Average time for laying units in the panel	Total No. of joints on the face of panel		Average time for finishing back joint of the panel	Total time required for the panel
				Stretcher course	Header course	Stretcher course 2Brk/ 1 Blk	Header course 1 Brk/ ½ Blk	Minutes	Horizontal	Vertical	Mts.	Mts.
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Traditional Bricks	384	41.44	41.86	39.22	55.98	43.96	93.08	16	280	11.70	104.78
2.	Modular Bricks	336	40.28	41.15	36.62	53.62	40.84	73.21	12	246	9.97	83.18
3.	Modular Blocks	168	42.76	27.33		44.97	39.52	51.20	12	162	9.77	60.97

bricks as compared to traditional bricks, appears to be due, as before, to the greater vertical area over which mortar is to be applied (32 sq. in. in case of modular brick as against 27 sq. in. in traditional bricks). The greater difference in case of modular bricks as compared to modular blocks, is caused by the need of handling 2 bricks *versus* 1 block in stretcher courses, even though the overall size and weights are nearly the same, while timings for header ends remain almost the same.

As before, the latter reason, viz. laying to string is responsible for the differences in time of laying for stretchers and headers in the three units. The traditional bricks having the longest sides (9″×4½″) takes more time than the modular bricks or modular blocks 8″×4″ and 8″×8″ respectively. The stretchers in modular blocks takes less time than the stretcher in modular bricks, because only one handling operation is involved instead of two. No significant difference is obtained in case of headers because half block is almost similar to a modular brick.

Timing for Panels

The average time for laying and finishing the panels, when proportionately reduced to that for an area of 40 sq. ft. work out as under:

	Time (min.) for laying 40 sq ft. panels		
	Panel only	Finishing of back joints	Total
Traditional bricks	89.86	11.29	101.15
Modular bricks	72.67	9.90	82.57
Modular blocks	47.9	9.13	57.03

Table 3

Showing Observations During Time Studies of Laying Brick Units

No. of course	Height of course from floor level in inches			Difference in height of course and stack in inches			Posture of brick layer		
	1			2			3		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
2	3.19	4.17	4.17	−12	−12	−12	Sitting	Sitting	Sitting
3	6.38	8.33	8.33	− 9	− 8	− 8	-do-	-do-	-do-
4	9.57	12.50	12.50	− 6	− 4	− 4	-do-	-do-	-do-
5	12.76	16.66	16.66	− 3	0	0	-do-	Standing	Standing
6	15.95	20.83	20.83	0	+ 4	+ 4	Standing	-do-	-do-
7	19.14	25.00	25.00	+ 3	+ 8	+ 8	-do-	-do-	-do-
8	22.33	29.17	29.17	+ 6	+12	+12	-do-	-do-	-do-
9	25.51	33.33	33.33	+ 9	+16	+16	-do-	-do-	-do-
10	28.70	37.50	37.50	+12	+20	+20	-do-	-do-	-do-
11	31.89	41.66	41.66	+15	+28	+28	-do-	-do-	-do-
12	34.08	45.83	45 83	+18	+36	+36	-do-	-do-	-do-
13	37.27	50.00	50.00	+21	+44	+44	-do-	-do-	-do-
14	40.45	—	—	+27	—	—	-do-	—	—
15	43.64	—	—	+33	—	—	-do-	—	—
16	47.82	—	—	+39	—	—	-do-	—	—
17	51.00	—	—	+45	—	—	-do-	—	—

Average time taken for laying corner units including plumbing and stringing in a course*										Average time taken for laying regular cycle of 4 bricks/2 blocks in a course				
4										5				
(a)				(b)				(c)		(a)		(b)		(c)
Stretcher course		Header course		Stretcher course		Header course								
No. of Bricks	Time in Sec.	No. of Bricks	Time in Sec.	No. of Bricks	Time in Sec.	No. of Bricks	Time in Sec.	No. of Blocks	Time in Sec.	Stretcher course	Header course	Stretcher course	Header course	
2	46.62	1	36.50	2	41.53	1	32.39	½	30.36	37.7	36 7	33.9	29.8	24.3
2	47.70	1	34 26	2	46.36	1	27.19	1	36.75	38.0	36.7	38.4	34.1	25.7
2	48.10	1	38.29	2	50.20	1	35.93	½	36.15	41.7	37.5	38.9	35.5	27.8
2	49.59	1	37.48	2	49.84	1	36.45	1	44.02	41.7	37.1	36.6	33.2	24.8
2	52.01	1	36.06	2	52.68	1	41.51	½	40.45	39.4	34.5	38.8	33.0	24.9
2	53.81	1	45.16	2	58.07	1	43.07	1	45.53	37.9	36.3	39.9	34.1	26.0
2	56.31	1	45.94	2	50.49	1	43.67	½	42.96	39.3	36.0	40.6	36.3	26.7
2	57.35	1	47.41	2	57.15	1	47.41	1	45.62	41.3	36.0	42.1	36.3	26.2
2	58.68	1	50.33	2	56.91	1	44.24	½	42.68	40.8	37.5	43.3	36.9	28.7
2	64.74	1	47.79	2	59.67	1	44.34	1	46.85	40.3	39.8	43.4	38.7	29.4
2	58.99	1	48.09	2	58.25	1	46.0	½	44.51	40.3	40.3	45.5	44.1	30.0
2	58.38	1	44.86	2	62.31	1	47 84	1	51.02	42.9	36.8	52.4	47.4	33.5
2	59.37	1	44.50	—	—	—	—	—	—	44.9	42.6	—	—	—
2	61.73	1	44.96	—	—	—	—	—	—	45.2	42.3	—	—	—
2	61.41	1	42.73	—	—	—	—	—	—	48.5	51.3	—	—	—
2	60.83	1	51.98	—	—	—	—	—	—	49.0	48.1	—	—	—

NOTE: 1. (a) Traditional Bricks (b) Modular Bricks (c) Modular Blocks.
2. * This does not include the time for cutting brick for quion closure since cut-bricks were supplied.
3. No observations made during laying the first course (see text of paper).

While no break up of the cycle into its constituent operations is available, this difference in timings can be mainly attributed to the size of units, which in turn effect, the number of blocks to be handled and laid, the length of horizontal/vertical surface on which the mortar is to be spread/applied, and, finally the number of front joints, which are finished as a part of the cycle. The timings for fixing the back joints are as under:

	No. of joints		Length of joints (ft.)	
	H	V	H	V
Traditional bricks	16	280	156	70
Modular brick	12	246	119	82
Modular block	12	162	119	54

The timing for finishing horizontal vertical joints could be, for simplicity, worked out on the basis of three simultaneous equations, involving the lengths of horizontal vertical joints. This shows that, as an approximation, finishing of vertical joints takes twice the time that of the horizontal joint.

Table 3—Effect of Height on Output

Table 3 shows that panels for traditional bricks require 17 courscs as against 13 course for modular bricks and blocks. The brick layer lays units in a sitting position upto a height of approximately 1′-3″ to 1′-4″ (5 courses in tradional bricks/4/courses in modular bricks blocks) beyond which he works in a standing position. The regular cycles for these units indicate that broadly speaking, the cycle time is the least for modular blocks followed by modular bricks (header courses), traditional bricks (header courses), modular bricks (Stretcher courses), and traditional bricks (stretcher course) in that order.

The relation between the height and output is brought out clearly in Fig. 4 which is really a combination of timings, for stretcher (or header) course, observed in alternate panels, laid in the same type of unit. It would be seen that the broad pattern is similar in the following respects : The output

(a) Decreases till the brick layer changes from the sitting to standing position at about 1 ft. height.

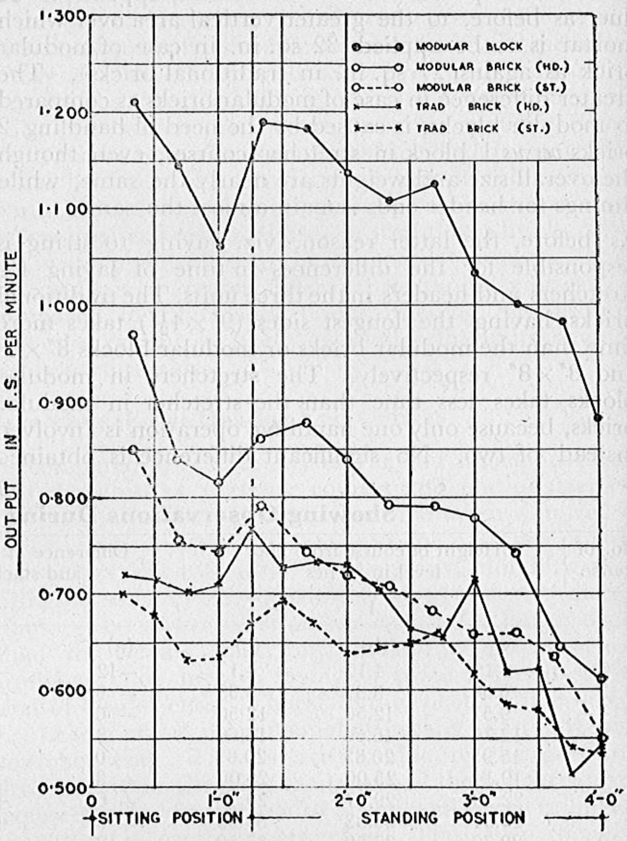
(b) Registers a more or less sharp increase in the courses immediately after the change over.

(c) Decreases till the output at about 2 ft. 9 in. to 3 ft. and is the same as that at about 1 ft.

(d) Continues to decrease till the full height of the wall is reached.

The reasons for this pattern can be easily established. In the sitting position, the movements of the brick layer are restricted and he tends to work in an increasingly restricted area as the relative distance (height between the levels of the course and brick stack,) decreases. When he gets up, his movements become free and different muscles are brought into play—which is responsible for the increase in output. As the work in continued, the advantage of free movements is counter balanced by the fatigue induced by the bending posture as well as the increasing distance between the stack and the course—resulting in decrease in output. These causes are also responsible for further

FIG. 4



Working-Heights of Layers
Output Vs Height of (Regular Cycles)

output. The optimum range of height appear to lie between 1 ft. to 2′-9″ from the floor. In actual practice, the header and stretcher courses would be alternated and the graph would represent a saw tooth pattern (typical graph for modular bricks shown in Fig. 5). It would however be seen that working posture of the brick layer affects the output in similar manner. The maximum output is achieved at the change over from sitting to standing position. Later on, the output has a decreasing trend, although alternate courses show sharp fluctuations due to alternating of header and stretcher courses.

Table 4—Accuracy of Results

Table 4 shows that in almost all the cases the desired accuracy of 95% confidence level with +5% precssion has been obtained. It is seen that greater accuracy has been obtained when the brick layer is working in sitting position than when he is working in standing position. This is attributed to the fact that the movements of the brick layer are confined when he is working in sitting position and thus there are less changes in his movements. The header courses show more consistent precision than the stretcher courses. This is due to the greater care required in adjusting stretcher along the string due to its longer length (9″ & 8″) than that required in header because of its shorter length (4½″ & 4″) for traditional and modular bricks respectively.

Table 5—Comparative Outputs and Economics

Table 5 shows that the output of the brick layer is highest with modular blocks and lowest with traditional

TABLE 4

Showing Number of Observations for Laying Units in Regular Cycles in a Course for 95% Confidence Level and ±5% Precision

Units	Posture of Working	Type of Course	Highest Reading (H) Seeds	Lowest Reading (L) Seeds	$\frac{H-L}{H+L}$	No. of Observations* Required	Observations Actually Taken	Percent Precision for actual Readings Taken
Traditional Bricks	Sitting	Stretcher	46.77	36.72	0.12	17	30	±3.6
		Header	40.60	33.43	0.095	12	20	±3.6
	Standing	Stretcher	46.98	37.20	0.116	17	20	±4.5
		Header	42.30	33.60	0.11	14	30	±3.3
Modular Bricks	Sitting	Stretcher	46.65	34.20	0.15	27	30	±4.0
		Header	37.67	30.50	0.105	14	30	±3.3
	Standing	Stretcher	50.92	36.75	0.16	30	30	±5.0
		Header	42.12	33.22	0.12	17	30	±3.6
Modular Blocks	Sitting		28.68	20.86	0.16	30	60	±3.5
	Standing		32.76	20.96	0.22	57	60	±4.9

*Obtained from Table No. 12 on page 371 of Motion and Time Study (Third Edition) by Marvin E. Mundel.

Table 5

Showing Comparative Output and Economics of Units

Sl. No.	Type of Unit	Brick layer's output per hour in sq. ft. of wall area	Increase in output in sq. ft. %	Brick layer's output per hour in cft.	Increase in output in cft. %	Mortar consumption per 100 sq. ft. of wall area in cft.	Savings in mortar consumption %	Cubic contents per 100 sq. ft. of walling for one brick/block thick wall: cft.	Savings in masonry consumption %	Cost of unit per 1000 Nos. in Rs.	Cost of 100 sq. ft. of wall area in Rs.	% saving in cost
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Traditional Bricks (a)	23.73	—	18.19	—	18.2	—	75	—	30.70*	55.08	—
2.	Modular Bricks (b)	29.05	21.4	19.38	6.54	13.4	26.6	66.7	11.1	29.91**	44.84	18.59
3.	Modular Blocks (c)	42.08	77.0	28.04	54.15	9.5	47.7	66.7	11.1	59.82***	37.60	31.74

*Control price of the coal burnt, first class Traditional bricks at kiln site at Roorkee in 1964—May.

**Rate of coal burnt, first class modular bricks at kiln site, being supplied to Heavy Electrical Engineering, Jawalapur.

***Assumed price of modular blocks, as these are not being manufactured at present. This has been taken as double the cost of modular bricks since its volume is double than that of modular brick.

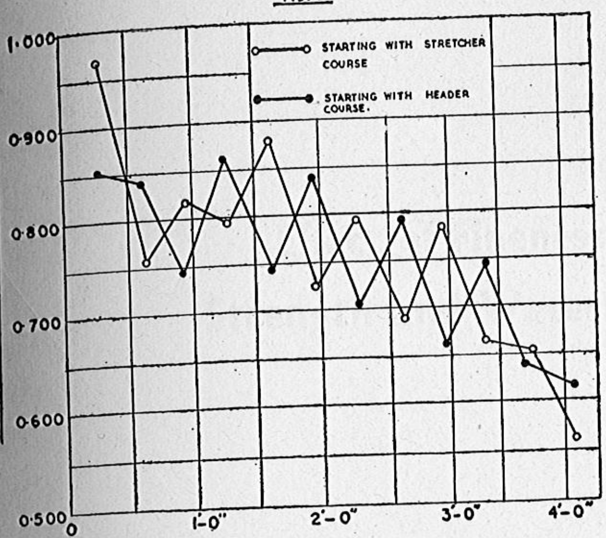
****The rate for Mason has been taken as Rs. 4 per day and that for helper Rs. 2 per day. The cost of cement is taken at Rs. 8.50 per bag and sand at Rs. 10 per 100 cft.

APPENDIX I

Observed Method and Standardisation

Sl. No. 1	Observed Method(s) 2	Standardised Method 3	Reasons for Selecting the Method 4
1.	*Wetting of Units* Sometimes wet units and sometimes omit wetting.	All the units soaked in water before use.	Essential for proper and better consistency in mortar use.
2.	*Stacking of Unit* The distance and height of stack variable (1½′ to 3′ and 3″ to 1′ respectively).	The stacks arranged at 2′—6″ from the wall and arranged to a height of 1′—3″ as shown in Fig. 3.	The distance of 2′—6″ provides minimum adequate free space for the brick layer to work. The height of 1′-3″ was selected to permit the brick layer to pick-up bricks without excessive effort.
3.	*Stringing and laying of brick units at ends of wall.* Arrange string at starting point. Then go to the other end and stretch string. Come back at starting point for laying brick units for the panel. This procedure was followed for all courses.	Stringing in the first course done in the same way. For subsequent courses, the brick layer arranged string in correet position for the next course as soon as he finished laying of last brick in the previous course.	This was done to eliminate one unnecessary movement of the brick-layer.
4.	Lay varying number of units (1 to 3) at the two ends of wall and then stretch the string.	*Traditional and Modular Bricks* Header course: Lay one brick at each end. Stretcher course: Lay two bricks at each end. *Modular Blocks* a) Lay one full block at each end in even courses. b) Lay half block at ends in odd courses.	One brick is sufficient for holding the string in place.
5.	Sometimes omit plumbing operations in laying end units.	Plumbing operations carried out for laying all end units.	Essential for good workmanship.
6.	*Laying of units in wall panel* Spread bed mortar for variable lengths (9″ to 18″) and place variable number of bricks/blocks.	Spread mortar corresponding to 4 bricks or 2 blocks (i.e. 16″ to 18″) and provide 4 bricks/2 blacks in one cycle.	Optimum length on which mortar can be spread by a mason standing at one place.
7.	Lift bricks either with the left or the right hand.	Lift bricks with the left hand.	The right hand has to hold the trowel and is not available for this purpose. This eliminates many unnecessary hand motions.
8.	Apply mortar to the side faces of bricks by either of the following methods: a) Hold brick in left hand, apply mortar on side and position brick in wall. b) Position brick in wall and then apply-mortar.	First position the bricks and the blocks and then apply mortar.	Represents the method commonly followed and found covenient by the brick-layer.
9.	Press the brick units in position by mason's hammer, trowel handle or hand (sometimes omit pressing altogether)	Use only mason's hammer or pressing the unit in position.	Essential for good workmanship and avoiding damage to trowel handle.
10.	Finish front joints for varying number of units (2 to 8)	Finish joints of the units laid in one cycle in each case viz. 4 bricks and 2 blocks.	Mason does not have to come back to finish the work.
11.	Change of posture from sitting to standing. a) 5 to 8 courses in traditional bricks. b) 4 to 6 courses in Modular bricks and blocks.	a) 5 courses in Traditional bricks b) 4 courses in Modular bricks/ blocks.	16″ height was found to be the convenient stage to change from sitting to standing posture.

FIG. 5



Working-Heights of Layers
Output Vs Height of Working Modular Bricks
(Using English bond i.e., alternate courses as—headers & Stretchers)

bricks. When compared with the output of traditional bricks, there is an increase in output by 77% and 21.4% in case of modular blocks and modular bricks respectively. This increase in output is attributed to the reasons given earlier at the beginning of discussion viz., the size of unit, the number of units required to be laid and the quantity of mortar consumed for a given area of wall.

Mortar Consumption

It shows that the consumption of mortar is highest with traditional bricks and lowest with modular blocks. When compared with the consumption of mortar in case of traditional bricks, there is a saving of 47.7% and 26.6% with the use of modular blocks and modular bricks respectively. This is attributed to the need of applying and spreading mortar for a greater length (226 inches in case of traditional brick) (173 inches in case of modular blocks and 201 inches in case of modular bricks).

Masonry Consumption

It is seen that the cubic contents for 100 sq. ft. one brick thick walling is 75 cft. in case of traditional bricks as against 66.7 cft. in case of both modular blocks as well as modular bricks. This is due to the fact that the traditional brick wall is 9″ thick while that with modular blocks and bricks is only 8″ thick.

Cost

At present only the traditional bricks are being manufactured by local kiln owners, while the modular bricks are deing manufactured by only one brick kiln owner in adjoining area, who is supplying such bricks to the Heavy Electricals at Jwalapur. The controlled price at kiln site shows that the price of modular bricks are 2.5% cheaper than traditional bricks. This indicates that there is no difficulty in moulding and firing of modular bricks. Since the modular blocks are not being manufactured on mass scale, while these are double in volume to that of modular bricks, the cost has been taken as twice. Thus by taking the costs given in Table 5, it is seen that the cost with modular blocks will be lowest, followed by modular bricks and traditional bricks in that order. Based on these costs, modular block work and modular brick work workout to be cheaper by 31.34 and 18.59 per cent respectively as compared to traditional brick work.

Conclusions

While these studies can only be regarded as indicative of the broad trends, they clearly establish that modular blocks and bricks show substantial advantages over the traditional bricks. These advantages consist of greater output in terms of square ft. of wall laid per hour, relatively lower cost of blocks/bricks, less mortar consumption and lesser weight. It also leads to other indirect savings in space occupied by walls and weights to be carried by the structural system and the foundations. Obviously modular block could only be used for unit thickness wall, while modular bricks could be combined to give wall thicknessess in multiples of 4″. The field investigations in progress are expected to yield realistic outputs for modular bricks in relation to traditional bricks and therby present a more complete analysis of the productivity pattern.

Another interesting conclusion is the substantially lesser time taken to lay the header courses in modular bricks. The appreciable saving in time of 11 per cent suggests that there is greater scope and advantages in using relatively more number of header courses than stretcher courses in modular brick wall, such as adopted in garden wall bond. Since brick walls are relatively stronger in compressive than in lateral strength, the use of greater number of header courses may also yield walls with relatively higher lateral strength and enable these walls to be used for higher unsupported heights or lengths in comparison to traditional brick walls. This however needs to be established by carrying out appropriate tests. The other tests about the strength, rain penetration and thermal conductivity of modular bricks blocks walls are also equally important to be carried out.

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