'CINVA' RAM AS A MANUALLY OPERATED CEMENT-SAND BLOCKMAKING MACHINE FOR LOW CEMENT MIXES

by

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Abstract

Production of cement-sand blocks is a popular industry and most of the production is done using blockmaking machines. Automatic or semi-automatic machines are used by large scale producers while manually operated machines are used by small scale producers. To satisfy the demand of the latter category, manually operated machines are locally manufactured now based on the principles of the 'CINVA' ram. An efficient manually operated machine for production of cement-sand blocks is an asset to the industry. Thus there is a need to study the use of the 'CINVA' ram to identify its shortcomings and how it can be improved for greater efficiency. This study was directed towards that need.

The study covered the range of cement-sand mixes useful for the production of low strength blocks for the more common applications up to two-storey high loadbearing walls. It consisted of producing at least 400 blocks and testing them to obtain important parameters which govern the satisfactory production and performance of blocks.

The results of the study highlighted the shortcomings of the 'CINVA' ram and the desirability of improving it for efficient performance. In addition, the recommended modifications are also presented.

1.0 Introduction

Production of cement-sand blocks is a very popular small scale self employment project. Desire for increased productivity at a small capital investment is creating a demand for manually operated blockmaking machines. As even the smallest imported blockmaking machine is not fully manually operated, few local fabricators have produced manually operated machines to fulfill this need. The cheapest version, which is very popular, is based on the principles of the 'CINVA' ram (see Figures 1(a), 1(b), 1(c) and 1(d)). The merits of this machine are its simple mechanism, possibility of operation with even one person, low capital and running costs, and complete manual operation.

The 'CINVA' ram was originally developed to produce blocks using very cohesive mixes such as soil-cement or cement-sand with a high cement content. As properties of lean cement-sand mixes which are less cohesive differ significantly, the original machine is unlikely to be suitable without modifications. Hence it was considered opportune to study the production of cement-sand blocks with low cement content mixes using a 'CINVA' ram so as to identify its limitations and also to determine how best to overcome them.

2.0 The Study

It was possible to base the study

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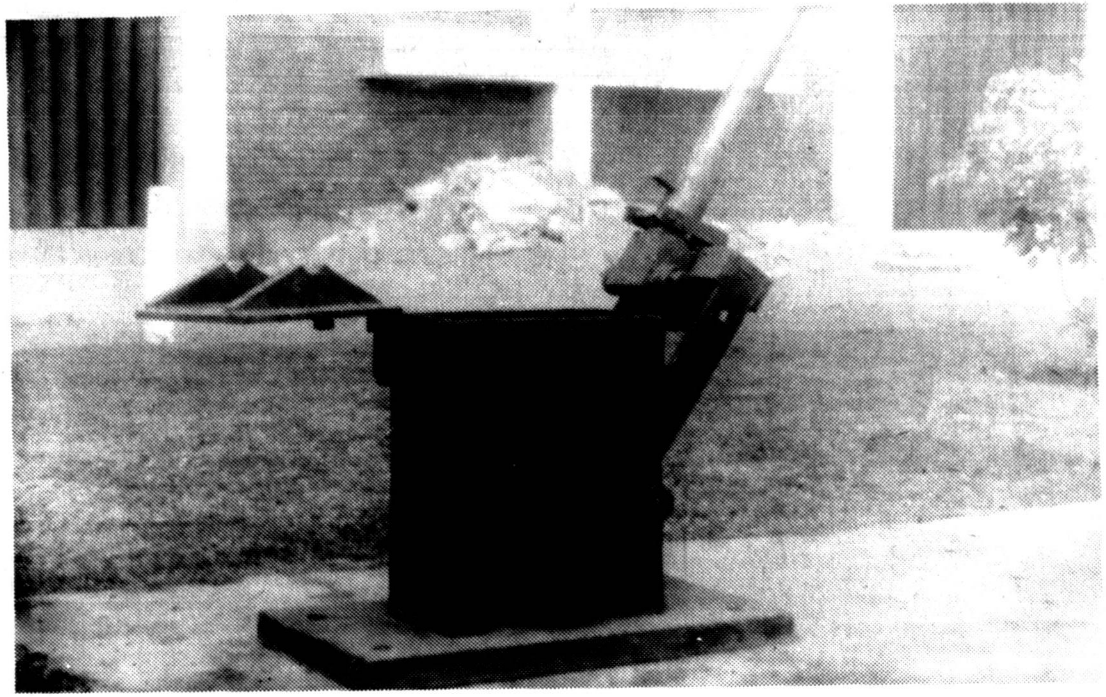


Figure 1 (a) 'CINVA' ram - Machine ready to accept the cement-sand mix (catch at the junction of two lever arm sections engaged)

Figure 1 (b) 'CINVA' ram - Compaction about to commence (catch at the junction of two lever arm sections disengaged)

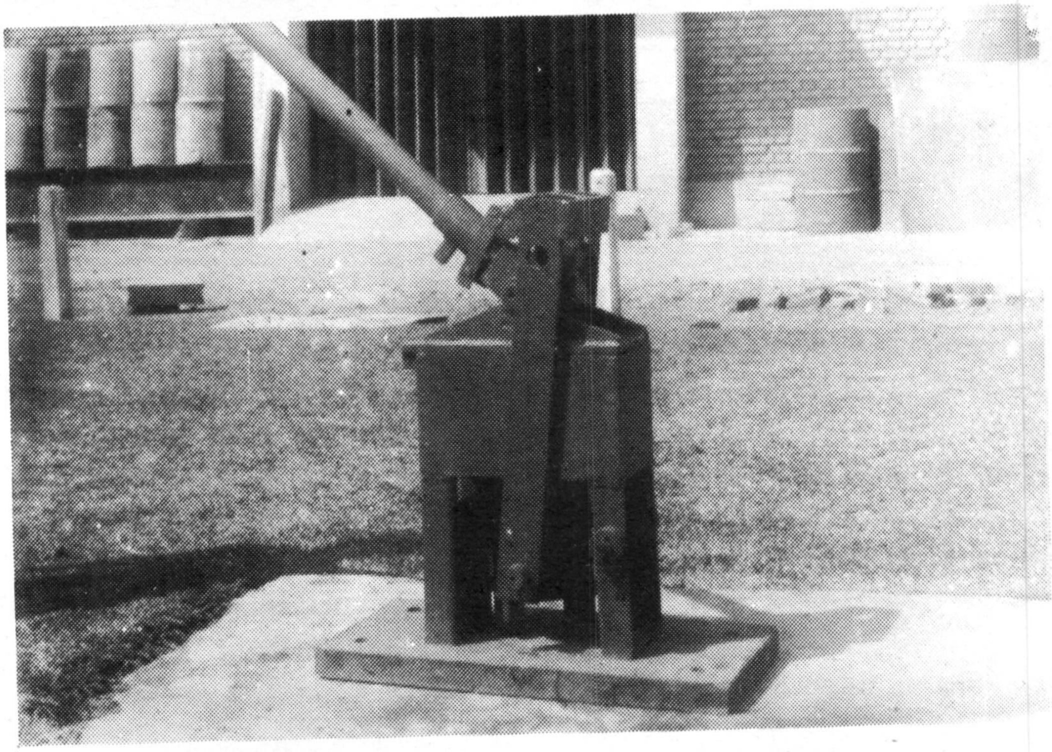


Figure 1 (c) 'CINVA' ram - Compaction completed (catch at the junction of two lever arm sections still disengaged)

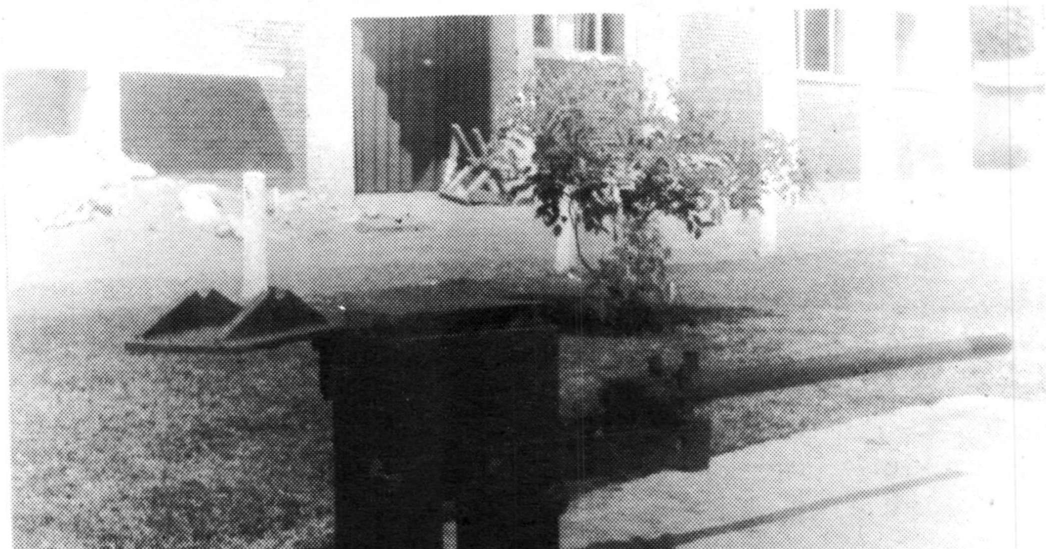


Figure 1 (d) 'CINVA' ram - Ejection of the cast block (catch at the junction of two lever arm sections engaged) on the 'CINVA' ram or the modified machines produced by local manufacturers. As it was neither possible to study the different machines of all the local manufacturers nor possible to select one without prejudice to others, original version of the 'CINVA' ram was used for the study. However, mixes used were of low cement content and low cohesion.

The main objectives of this investigation were: (a) to study how basic properties such as crushing strength, density and drying shrinkage of cement-sand blocks produced by the machine vary with different mortar mixes; (b) to study how parameters, such as tolerance of dimensions, number of breakages and mode of breakage during demoulding which are indicators of the efficiency of the machine vary with different mortar mixes; (c) to determine the best mix proportion and water/cement/ratio for the block-making machine used in this study; (d) to identify suitable applications for the blocks produced under the best operational conditions of the machine; (e) to identify the deficiencies of the blockmaking machine when used for the production of low cement content cement-sand blocks, and (f) to determine the means by which above deficiencies can be overcome.

3.0 Test programme and its formulation

The main factors that affect the production of blocks when CINVA ram is used[5] are:- (a) mix proportions; (b) water/cement ratio; (c) type and grading of aggregate; (d) type of cement; (e) type and size of blocks; (f) percentage compaction by volume; (g) compactive effort; (h) compressive force applied during compaction of the block; (i) play between the ram and mould; and (j) curing of the block.

Mix proportions, by volume, were varied in the test programme to give the following cement-sand mixes: 1:4; 1:6; 1:8 and 1:10. These mixes cover the normal range of cement-sand mixes[1] used in production of blocks. Water/cement ratio was maintained at 0.4, 0.5, 0.6 and 0.7 to cover the range of values[1] suited for cement-sand machine cast block production.

Factors (c), (d), (e), (f), (g), (h), (i) and (j) above were not varied as this study does not deal with optimization of the production process but deals only with feasibility of using the machine for cement-sand block production. Type of aggregate used was river sand and the grading of aggregate conformed to Zone 2 of the BS 882[2] requirements for fine aggregate. Type of cement used was ordinary portland cement. The block produced was of solid type and its nominal dimensions were 290mm long x 140mm wide x 140mm high. The fact that the dimensions do not correspond to standard sizes[3] of cement-sand blocks was ignored as the machine can be altered to produce standard sizes and as a decision was taken earlier to use the original version of the CINVA ram machine.

There was no facility in the machine to fix or vary, as desired, the percentage compaction by volume. Thus this variable changed arbitrarily on its own and the values observed were recorded.

The compactive effort was confined to one compression cycle only as repeated compression cycles (i) will increase the labour cost; (ii) may not provide significantly greater compaction as the force applied is predominantly static; and (iii) may cause some damage to the block due to repeated movement in the mould.

A compressive force of up to 15kN can be applied for compaction of the block as the lever arm magnifies the applied force by 16 times. As only a moderate effort was exerted the compressive force applied was measured to be around 10kN and this was considered to be a suitable value for efficient operation of the machine.

The existence of any play between the mould and the ram will (i) cause the bed face of the cast block to be sloped; (ii) cause breakages in the blocks cast due to jerky movement of the ram; (iii) cause a reduction of the effective compacting force due to appearance of frictional forces from contact between metal parts formed by displacement of the lubricant layer between the sliding faces; and (iv) cause mortar to go between sliding faces leading to development of frictional forces which reduce compaction and accelerate wear of the machine. A 2mm play was found on the length side as well as the width side and this was not considered to be harmful.

Curing was commenced 24 hours after casting and water was sprinkled for 7 days on blocks covered with gunny bags so as to keep them continuously moist during this curing period.

For each condition representing a particular mix proportion and a particular water/cement ratio, at least 25 blocks were cast. Mix proportions and water/cement ratios studied are given in Table 1.

The main properties and parameters observed in the test programme were: (a) occurrence of defects during casting; (b) tolerance of block dimensions; (c) density; (d) crushing strength; and (e) drying shrinkage. All the blocks were used for observing the property (a) above, while all non-defective blocks were used for observing (b) and (c) above. Ten blocks were used for each crushing strength test, while four blocks were used for each drying shrinkage test. Above tests were conducted in accordance with BS 6073[4]

4.0 The test results

Casting of blocks, in any category represented by a particular mix proportion and a particular water/cement ratio, was done in several batches in order to make results representative of the incidental variations likely in cement and sand. Where sand was found to be wet, its moisture content was determined and suitable adjustments were made to the quantity of water added to attain the requisite water/cement ratio.

Casting time of a block (see Table 1) reduced as workability improved for each mix proportion. However, the optimum casting time may not be the minimum and will depend on other considerations such as breakages and crushing strength. The above casting time was taken as the time taken to produce a block with one operative using freshly prepared cement-sand mortar. Further reductions in casting time is possible by using two operatives with the unskilled person employed for filling the empty mould (Figure 1(a)), closing the filled mould, compacting (Figure 1(b) & 1(c)), and removal while the skilled person is assigned to move the lever to a vertical position (after filling and closing mould by the companion) and eject the block from the mould (Figure 1(d)). Use of two operatives will also help to maintain, consistently, the reduced casting time by minimising operator fatigue. This is attained by reducing and better timing of the work movements of each operative as stated above.

Percentage of defectives shows that blockmaking machine works best for 1 cement : 4 sand mix with a water/cement ratio of 0.7 (see Table 1) where percentage of defectives was nil. Mix proportions 1:8 and 1:10 cannot be used for production of blocks with the water/cement ratio in the range from 0.4 to 0.6, as the mix is too powdery and block collapses as it comes out of the mould. Defectives, when few, are not very harmful as mortar can be recycled. As percentage of defectives is considerable for

Mix proportion by volume (cement:sand)	Property considered	Water/cement ratio			
		0.4	0.5	0.6	0.7
1:4	Casting time per block(minutes)	2.6	2.0	1.8	1.5
	Percentage of defectives	63.3%	48.3%	15.4%	0%
1:6	Casting time per block(minutes)	4.3	3.6	2.2	2.0
	Percentage of defectives	78.8%	59.3%	46.7%	30.8%
1:8	Casting time per block(minutes)	*	*	*	2.7
	Percentage of defectives	100%	100%	100%	41.4%
1:10	Casting time per block(minutes)	*	*	*	3.2
	Percentage of defectives	100%	100%	100%	73.3%

* All blocks defective

Table 1 - Casting time per block and percentage of defectives of different mixes

certain mixes, the blockmaking machine can only be used for some mixes only. Thus it is not possible to produce blocks of a desired strength and the mix suited for the machine is also too costly. Hence it is very necessary to incorporate suitable modifications to the machine to reduce formation of defectives.

The modes of failure observed in the defective blocks were: total collapse, edge/side collapse, or cracking. Total collapse was due to non-cohesive nature of the mix which is too powdery due to insufficient cement, water, or both. Cause for edge/side collapse was the insufficient cohesiveness of the mix along with disturbances occurring in the machine. Failure by cracking was caused by disturbances in the machine as before, but the mix is generally found to have improved cohesiveness. The above failure modes occur depending on the cohesiveness or stickiness of the mix. It is also worthwhile noting that when water content is too high cement slurry separates and comes to the top of the block with excess water draining out of the mould. Increased presence of fines in the aggregate is also found to increase the cohesiveness of the mix.

Dimensions of blocks were measured in accordance with BS 6073[4] by taking four measurements for length, seven measurements for width and six measurements for height at the specified locations of the block. Observed deviations are shown in Table 2 along with permissible deviations of BS 6073[4]. Deviations on length and width were within permissible limits. Although for average width permissible deviation was 4mm (+2 to -2) while observed deviations varied from 0 to 3mm, average width did not satisfy the specified requirements as the mould was undersize. Increasing the width of the mould by 3mm would be the remedy. Deviations on height were satisfied by blocks of some mixes only. Change in mould height will not help here, and the necessary remedial action is to control the height by placing a stop for the lever movement during compaction of the block.

Observed values of block density are shown in Table 3. Densities of individual constituents of the mix are such that, when effect of compaction is disregarded, block density decreases for a particular mix proportion as water/cement ratio increases. For the same reasoning, block density increases for a particular water/cement ratio as the sand content of the mix increases. Generally these relationships can be seen in the results except where improved compaction seems to increase block density for water/cement ratio of 0.6 and 0.7 and mixes of 1:4 and 1:6. However, the observed variation of block density is only 3.1% with a minimum block density of 1767.7 Kg/m^3 indicating that the machine achieves the necessary compaction satisfactorily.

Weight of a block was found to vary between 9 to 10.5 kg. It is generally considered that for one-handed laying, weight of block should be preferably less than 9 kg while for two-handed laying, weight of block should be preferably between 9 kg to 32 kg. Hence these blocks are difficult to place with one hand and too easy for laying with both hands. Thus it is better to adopt standard sizes for the mould of the machine.

Observed values of block crushing strength are shown in Table 3. Wide variations observed underline the need to control strictly the water/cement ratio and the mix proportion to obtain consistent values of block crushing strength. The highest block crushing strength observed of 7.84 N/mm^2, is suitable for 3-storey loadbearing walls when used with a mortar[8] of designation (iv) for blocklaying. The lowest block crushing strength observed of 1.01 N/mm^2, is suitable for single-storey loadbearing walls

Mix proportion by volume (cement:sand)	Dimension considered	Water/cement ratio				Permissible deviations
		0.4	0.5	0.6	0.7	
1:4	Length(mm)	0 to -4	0 to -3	0 to -3	0 to -3	+3 to -5
	Width(mm)	-1 to -4	-2 to -4	-1 to -3	-2 to -4	+4 to -4
	Height(mm)	+3 to -4	+2 to -7	+7 to -3	+1 to -3	+3 to -5
	Average Width (mm)	-1 to -4	-2 to -4	-1 to -3	-2 to -4	+2 to -2
1:6	Length(mm)	-2 to -4	-3 to -4	-2 to -4	-2 to -4	+3 to -5
	Width(mm)	-2 to -4	-2 to -4	-2 to -4	-2 to -4	+4 to -4
	Height(mm)	+1 to -7	+1 to -7	-1 to -8	+1 to -6	+3 to -5
	Average Width(mm)	-3(all same)	-3(all same)	-2 to -4	-2 to -3	+2 to -2
1:8	Length(mm)	*	*	*	-2 to -4	+3 to -5
	Width(mm)	*	*	*	-2 to -4	+4 to -4
	Height(mm)	*	*	*	+1 to -6	+3 to -5
	Average Width(mm)	*	*	*	-3 to -4	+2 to -2
1:10	Length(mm)	*	*	*	-1 to -4	+3 to -5
	Width(mm)	*	*	*	-2 to -4	+4 to -4
	Height(mm)	*	*	*	0 to -7	+3 to -5
	Average Width(mm)	*	*	*	-3 to -5	+2 to -2

*All blocks defective

Table 2 - Dimensional deviations (mm) of blocks of different mixes

Mix proportion by volume (Cement : sand)	Property considered	Water/cement ratio			
		0.4	0.5	0.6	0.7
1:4	Density(kg/m³)	1790.2	1767.7	1779.7	1802.4
	Crushing strength (N/mm²)	2.60	6.11	7.84	7.01
	Drying shrinkage(%)	0.0381	0.0391	0.0420	0.0392
1:6	Density(kg/m³)	1793.8	1768.2	1795.7	1805.7
	Crushing Strength (N/mm²)	1.05	3.42	3.56	3.56
	Drying shrinkage(%)	0.0378	0.0387	0.0409	0.0388
1:8	Density(kg/m³)	*	*	*	1813.8
	Crushing strength (N/mm²)	*	*	*	1.85
	Drying shrinkage(%)	*	*	*	0.0371
1:10	Density(kg/m³)	*	*	*	1823.2
	Crushing strength (N/mm²)	*	*	*	1.01
	Drying shrinkage(%)	*	*	*	0.0360

* All blocks defective

Table 3 - Density, crushing strength and drying shrinkage of different mixes

when used with the above mortar designation which is a compatible weak mortar. As the main demand is for single and two-storey constructions using a blocklaying mortar of designation (iv), block crushing strength values of 1.0 (1:8 mix and water/cement ratio of 0.7) and 2.5 (1:6 mix and water/cement ratio of 0.5), respectively, are adequate for those applications. But the percentage of defectives for the above mixes are considerable. Also, the mix for which the machine operates with an acceptable level of defectives provides blocks too strong (7.01 N/mm²) for the common applications and better suited for 3-storey loadbearing walls. Hence machine should be improved to keep the percentage of defectives low and this can be achieved by minimising the disturbances of the block during production.

The observed values of drying shrinkage (see Table 3) were less than the maximum permissible value of 0.5% specified in BS 6073[4] and hence can be considered as satisfactory. The maximum variation of drying shrinkage was only 16.6% and drying shrinkage does not appear to be very sensitive to changes in the mix proportion and water/cement ratio within the ranges studied. The good quality of aggregate also would have contributed to lower shrinkage.

Wetting expansion of blocks is unlikely to be important as drying shrinkage is small. This is so as the irreversible part of shrinkage represents[6] between 0.3 and 0.6 of the drying shrinkage and the maximum permissible value of wetting expansion[7] is 0.03%.

5.0 Modifications for improved performance

The main shortcomings highlighted by the feasibility study were:-

(a) For 1 cement: 4 sand mix with a water/cement ratio of 0.7, no defectives occurred. From 1 cement: 8 sand mix and 1 cement: 10 sand mix with water/cement ratio ranging for 0.4 to 0.6, blocks could not be cast as mixes were too powdery. With other mixes studied blocks could be cast, although percentage of defectives was considerable. A strong need exists to eliminate or substantially minimise defectives from these mixes; (b) The block making machine operates best for one mix (1 cement: 4 sand and water/cement ratio of 0.7) only. As that mix is too costly due to high cement content, it is necessary to modify the machine to make it operate efficiently for a range of mixes, particularly low cement mixes which are economical. This can be done by reducing the defectives in casting; (c) Mode of failure by total collapse indicates that the mix is too dry and requires adjustment in constituents to make it cohesive. Failure by edge/side collapse and failure by cracking both occur due to disturbances in the machine with the former type prevalent in less cohesive mixes while the latter type is more common in moderately cohesive mixes. The disturbances of the block occur when lever is to be lowered immediately after compaction (Figure 2(b)) to open the mould, when lever comes to a stop before ejection commences, ejection movement (Figure 2(c)) and when block along with the timber base plate is removed from the machine (Figure 2(d) & 2(e)); (d) Measurement of dimensions of blocks revealed that the requisite tolerances for length and width could be attained, while the tolerance for height could not be achieved. This can be remedied by placing a stop for the lever movement during the compaction of the block; (e) As the machine achieves the necessary compaction as indicated by small variation in block density and a minimum block density of 1767.7 kg/m³, there is no need to change the lever arrangement used to apply the compaction force; (f) As the weight of block is unsuitable for either one-handed or two-handed laying, mould should be changed to comply with standard sizes[2,7]. Although overall block size can be reduced by placement of spacers, for efficient production, the blockmaking machine of this type should be confined to one overall size only. Trials conducted indicated that hollow blocks of the same overall size can be produced by having a timber base plate with required hollows, supported by a steel plate fixed with timber blocks to form the required hollows (see Figure (e)); (g) The mix for which the machine works best is too strong for common applications. Leaner mixes should be used to obtain blocks of crushing strength adequate for common applications, with the machine modified to reduce percentage of defectives; (h) As the drying shrinkage and wetting expansion of the blocks produced are satisfactory, these properties require no improvement. Attention may be required only if poor quality aggregates or still higher cement contents are to be used.

To overcome the above shortcomings, the following modifications are recommended to the machine used in this study and to the mixes used:-

i) Mix used should neither be too powdery nor too wet, but sufficiently cohesive;

ii) When lever is to be lowered immediately after compaction to open the mould catch (see Figure 2(b)) should be removed first to avoid any disturbance to the cast block in the mould. Lever should also be gradually brought to rest on the stop before commencing ejection;

iii) Stop which prevents lever from further movement after ejection of the block (see Figure 2(c)) should be free to rotate and hence should incorporate a roller bearing within it. Surfaces causing sliding, during the ejection stroke, should also be well greased to prevent any jerky movement;

iv) Height of the mould should be such as to accommodate a timber base plate under the cast block to minimise disturbances during removal of the block. Timber used should be at least 20mm thick and preferably, radial sawn to reduce dimensional variations in service. Harder timber species will minimise wear;

v) Height of the mould should also accommodate a steel base plate with rollers welded onto it, and placed directly under the timber base plate. Along with two steel rods, this helps to remove blocks without any disturbance (see Figure 2(d));

vi) A stop should be positioned (see Figure 2(a)) to maintain maximum lever movement constant during compaction of the block, thus enabling attainment of specified tolerances for height of block;

vii) In the case of hollow blocks, steel plate mentioned in (v) above should also contain timber hollows fixed to it (see Figure 2(e)).

Some of the modifications mentioned above have already been incorporated by some local manufacturers who market modified versions of the 'CINVA' ram. However, all these modifications were not found to be incorporated by any local manufacturer.

6.0 Main findings

The main findings of this study were:

a) to obtain the best productivity from the blockmaking machine it is necessary to use two operatives;
b) For 1 cement : 4 sand mix with a water/cement ratio of 0.7, number of defectives was nil while for 1 cement : 8 sand and 1 cement : 10 sand mix with water/cement ratio ranging from 0.4 to 0.6, blocks cannot be cast at all. For other mixes blocks can be cast but percentage of defectives was considerable and hence machine should be improved to reduce defectives from those mixes;
c) 'CINVA' ram blockmaking machine

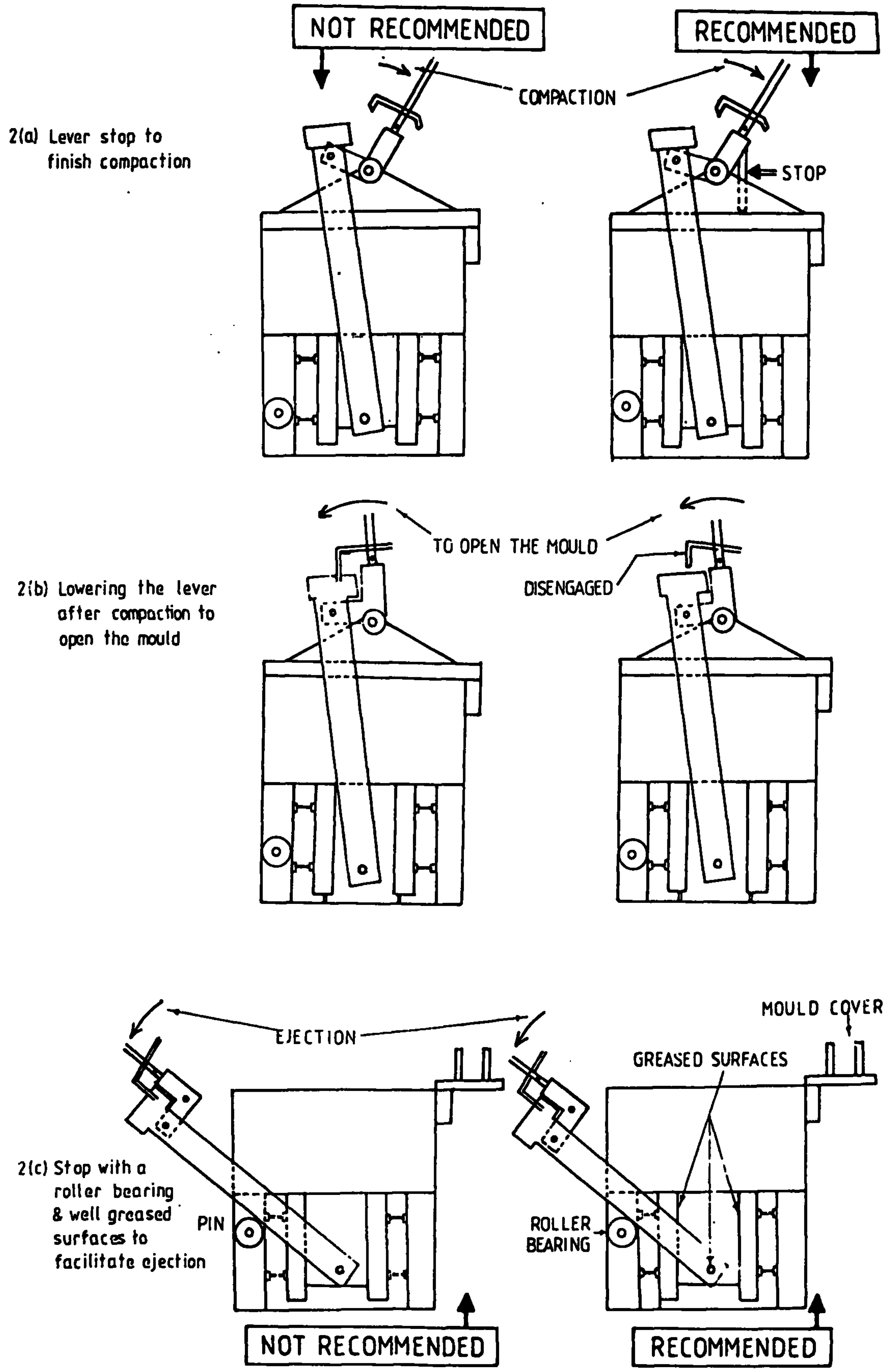
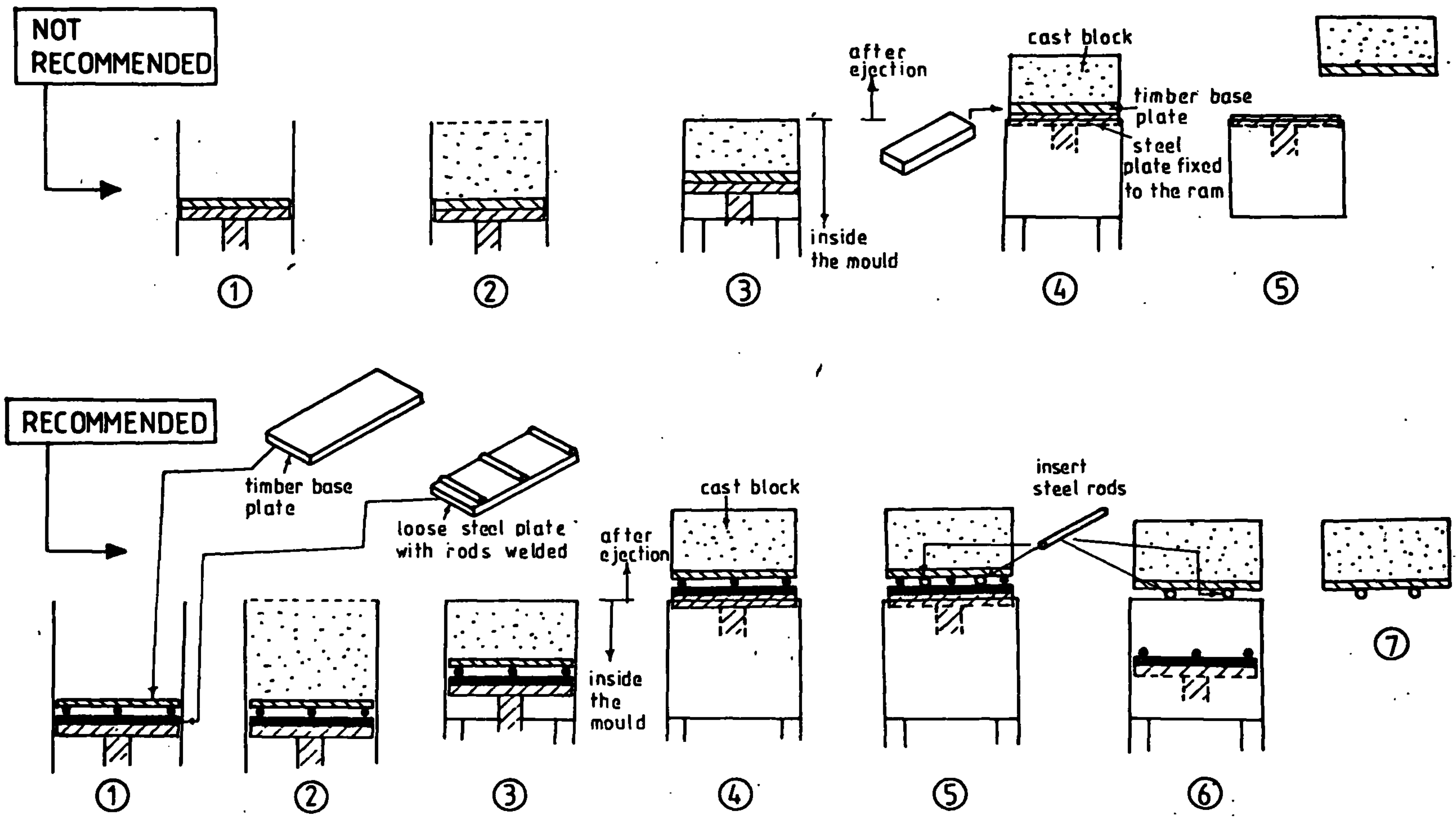
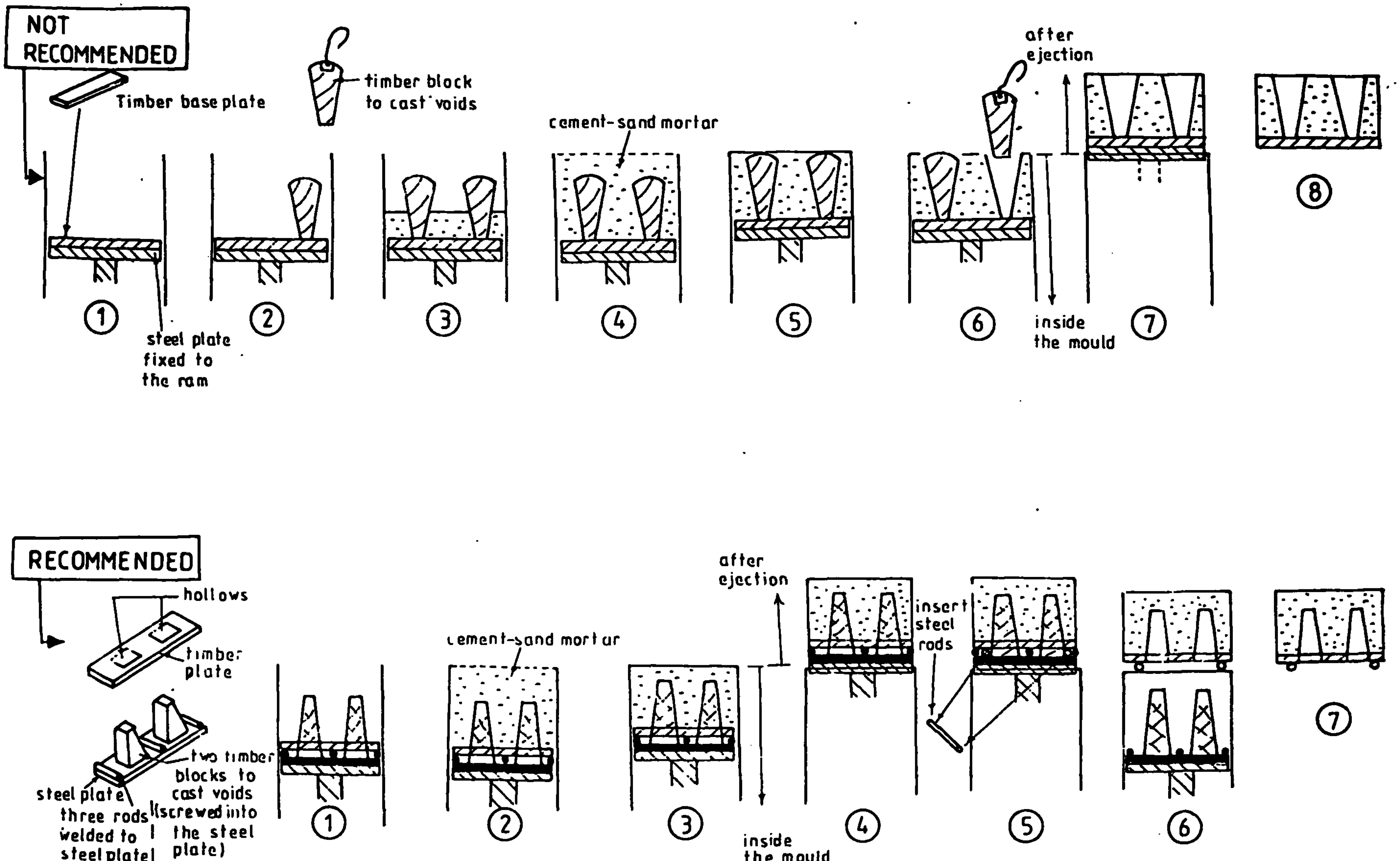


FIGURE 2-[2(a) to 2(e)]- SOME OF THE MODIFICATIONS RECOMMENDED (Continued)



2(d) Removal of solid blocks

FIGURE 2-[2(a) to 2(e)]-SOME OF THE MODIFICATIONS RECOMMENDED (Continued)



2(e) Removal of hollow blocks

FIGURE 2-[2(a) to 2(e)] - SOME OF THE MODIFICATIONS RECOMMENDED (Continuation)

was found to operate efficiently for one mix only with the mixes studied. Hence it is necessary to modify the machine to enable it to operate on a wide range of low cement mixes so that machine can be made versatile;

d) The modes of failure observed in the defective blocks were total collapse, edge/side collapse, and cracking of the block. These modes occur depending on the cohesiveness of the mix. The first mode of failure can be minimised by adjusting the mix to improve its cohesiveness, while the latter two modes can be minimised by preventing disturbances in the operation of the machine;

e) Requisite tolerances for length and width of a block can be easily attained. To achieve specified tolerances for height of a block, a stop (see Figure 2(a)) should be positioned to maintain maximum lever movement constant during compaction of the block;

f) Observed variation in density of only 3.1% with a minimum block density of 1767.7 kg/m^3 indicates that the machine achieves the necessary compaction of the block;

g) For one-handed or two-handed laying to be done conveniently, size of the mould should be changed to standard sizes[2,7]. Where necessary hollows should be incorporated into the block;

h) Block crushing strength values indicate that the mix where percentage of defectives is minimal and acceptable, is too strong for common applications. Suitable mixes were identified, but for the production to be economical with these mixes percentage of defectives should be reduced by incorporating recommended improvements to the machine;

i) Drying shrinkage and wetting expansion of blocks, produced by mixes within the range of mix proportions studied, cause no concern; and

j) Modifications recommended for improved performance were found to be partly used by local manufacturers already, but all the modifications were not found to be used by any manufacturer.

7.0 References

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