Labour-Intensity, Productivity and Performance of Locally Developed Low-Cost Housing Materials and Techniques

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Synopsis

The Building Research Institute of the State Engineering Corporation has developed several low-cost substitutes for the conventional building materials used in Sri Lanka. The substitute materials are especially suitable for self-help or self-built housing. The present paper evaluates the labour-intensity, productivity and performance of these low-cost materials and techniques.

It is shown that the low-cost substitutes, in as much as they are cheaper, are also more labour-intensive than the corresponding conventional constructions and therefore their use could lead to employment generation. Though the productivity of the low-cost tecniques is lower, output levels compatible with targets set can normally be achieved by increasing labour strength. The low-cost materials, it is concluded, perform more efficiently than the conventional building materials available at present.

1. Introduction

Traditionally house building in Sri Lanka has been labour-intensive. Common clay bricks set in cement/lime mortar for walls and foundations and clay tiles laid on timber scantlings form the traditional construction system, except for factory-produced cement all materials are produced on small-scale using local resources of surface clays, limestone and wood. Building crafts are generally well-known and dwellings are built entirely with on-site labour.

In recent times the house building industry has faced several difficulties. The oil crisis had its repercussions on transport costs of building materials which at present contribute to 60-75% of on-site prices. The unprecedented upsurge of construction activity in the Island during the past 2 years in the housing sector and in other constructions in the accelerated Mahaveli project and free trade zone development area– has resulted in a heavy demand for traditional building materials and consequently led to spiralling of costs.

Housing costs have therefore multiplied. A recent study shows, for instance, that almost 92% ofthe households in the City cannot afford to own even the cheapest traditional house of 23 m^2 (250 ft^2) ref. (1).

The construction of the planned 100,000 houses with traditional building materials and methods in such a perspective would involve not only a massive investment in financial terms but also a severe drain on natural resources of the Island; continued quarrying for clays would mean an encroachment on valuable agricultural land and felling timber and consequent denudation of forests would concern the environmentalists.

To respond to this situation the Building Research Institute has developed several low-cost housing materials and techniques.

The Government in an effort to bring down the construction costs and also to mobilize the participation of the population has planned to build half the total numbet of houses by self-help. The developments in low-cost housing materials and techniques have therefore taken this important input into account.

Among the low-cost housing materials and techniques perfected by the Institute are the substitutes for common clay bricks, clay roofing tiles, timber roof scantlings, timber door/window frames, brass hinges and the associated techniques of construction. They are described in detail elsewhere[2].

The purpose of the present paper is to evaluate the labour-intensity, productivity and the consequent effect on speed of construction and the performance of houses built with the low-cost materials.

2. Low-cost Materials and Techniques

We shall briefly describe here the characteristic features of the low-cost housing materials and techniques developed by the Building Research Institute. Further details are found in reference. (2)

2.1 Walling Materials

Two substitutes developed for common clay bricks are :

(a) Soil, Cement blocks and bricks.
(b) Cement-sand bricks.

The soil-cement blocks are of size 295 x 140 x 90 mm. (11½ x 5½ x 3½ in.) and the soil-cement bricks are of the same size as the Sri Lanka standard clay brick, viz. 210 x 100 x 65 mm. (8" x 4" x 2½ in.). They are made by pressing a mixture of lateritic soil and cement in the proportion 1 : 25 in a hand-operated machine called Sinha Ram (Figure 1). The blocks (or bricks) which can be removed from the press immediately after pressing, develop strength gradually to attain the strength requirements for load bearing walls in 28 days.

However walls of height upto 1 m. (3.3 ft.) can be built with soil-cement blocks (or bricks) immediately after casting and to storey height after 7 days. A cement-soil-sand mortar (1 : 5 : 10) is used for jointing. Four men can produce 800 bricks or 1500 bricks on one machine in 8 hours. The blocks which can be built into a 150 mm. (6 in.) wall can replace the 225 mm. (9 in.) clay brick work including load bearing walls and foundations. The cost saving over conventional one-brick walls is 70%. (Note: The cost figures and therefore comparisons given in the present paper include labour and material costs and excludes overhead costs unless otherwise mentioned.

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Pricing is as at October 1979). Soil-cement bricks which can be built into $4\frac{1}{2}$ or 9 in. walls are 45% cheaper than the equivalent clay brick work. (Table 4).

Cement-sand bricks are of the same size as the common clay bricks and are made by pressing a mixture of cement and sand in the proportion 1 : 12 in a simple timber mould. Pressing is done manually with the help of a block of wood which is driven by tapping. The cement-sand brIcks have smooth cement faces and comparable strength to common clay bricks. They can be built with cement/sand mortar for all load bearing and non-load bearing walls. Cost savings are about 20% compared to conventional clay brick work. But additional savings upto 50% are accrued since these constructions do not need plastering (c.f. para. 5).

Both these substitutes can be produced on the site by unskilled labour and are therefore especially suitable for self-help construction. Lateritic soils are available in many parts of the Island and very often at no cost on site levelling. The cement-sand bricks which can also be cast with sea sand (after a simple treatment) will be still more economical in coastal areas.

2.2 Floor Paying Materials

Both soil-cement bricks and cement-sand bricks described in the foregoing paragraphs can be used in floor paving in place of clay bricks. In such uses they can be laid in cement mortar and cost savings are of the order of 25%.

2.3 Roofing Materials

A cement half-round tile which can be cast on the site has been developed (Figure 2). It can be laid over conventional reepers spaced $13\frac{1}{2}$ in. (340 mm.). The simple casting procedure is described in detail in the reference [3]. These tiles, which can be coloured red if necessary by well-known simple chemical processes, cost as much as the equivalent half-round clay tile.

Two substitutes for roof scantilings are available, viz. round pole construction and R.C. rafters. Round poles which are available as thin...gs can be used in place of sawn timber in roof scantlings. A 90 mm. ($3\frac{1}{2}$ in.) round pole can be used in place of the conventional 50 x 100 mm. (2 x 4 in.) roof rafters. The method of fixing 90 mm ϕ round poles to lay half-round tiles and other roof coverings have been studied and perfected by the Institute (Figure 3). The half-round tiles on timber round poles are 40% cheaper than the half-round clay tiles on sawn timber scantlings (and 50% than the Calicut tiles on sawn timber scantlings). The R.C. system consists of using a 50 x 100 mm. R.C. roof rafter which can be cast on the site and a 75 x 100 mm. plain concrete cast in-situ wall plate in place of the conventional timber scantlings. Method of fixing timber reepers on R.C. rafters and support connections have been perfected. R.C. system with cement half round tiles could save about 20% in roofing costs.

TABLE I

(1) Construction	(2) Total cost per m²	(3) Labour cost	(4) *Labour cost* ÷ Total cost	(5) Cost Saving	(6) Productivity man hours per m²
	Rs.	Rs.	%	%	
1. **Half brick walls (unplastered)**					
Soil-cement half brick wall (110 mm.)	20	10	50	45	4
Cement sand half-brick wall (110 mm.)	29	9	31	19	4
Common clay half-brick wall (110 mm.)	36	7	19	—	3
2. **Solid one-brick wall** (unplastered)					
Soil-cement block work ... (150 mm.)	21	7	33	70	3
Cement sand brick work ... (225 mm.)	54	16	30	21	7
Common clay one-brick wall (225 mm.)	68	12	18	—	5
3. **Floor**					
Soil-cement block paved cement rendered ...	27	10	37	29	4.3
Cement-sand brick paved cement rendered	29	11.50	40	24	5
Common clay brick paved cement rendered	38	10	26	—	4.3
4. **Roofing**					
Cement half-round tiles on R.C. rafters and wall plates and timber reepers ...	92	27	30	19	12
Cement half-round tiles on round pole rafters and timber reepers	68	12	18	40	4.5
Burnt clay half round tiles on 50 x 100 mm. timber rafter and 25 x 50 mm. timber reepers	113	9	8	—	3.5
5. **Hinges**					
Low cost M.S. pivot hinge... 75 x 25 mm.)	3 per pair	0.75 per pair	25	57	—
Brass butt hinges ... (75 x 75 mm.)	7 per pair	—	—	—	—
6 **Door Frame** (2.1 x 0.85 m.)					
Low cost rebated wall edge in cement mortar and thin concrete lintel	37.50 per unit	20	53	69	8
50 x 100 mm. timber door frame	120 per unit	40	33	—	16
7 **Window frame** (0.6 x 1.2 m)					
Low cost rebated wall edge with cement mortar and thin concrete lintel	25	13	50	67	5.25
50 x 100 mm timber window frame	76	20	26	—	8

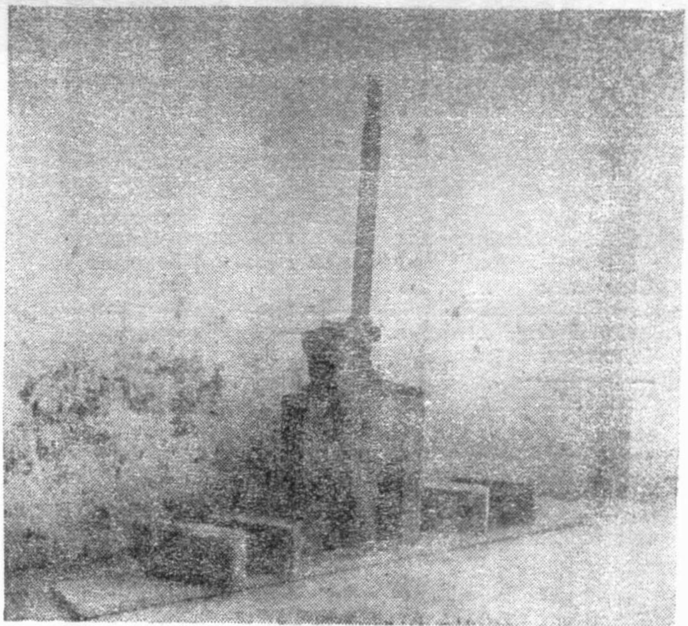

Fig. 1

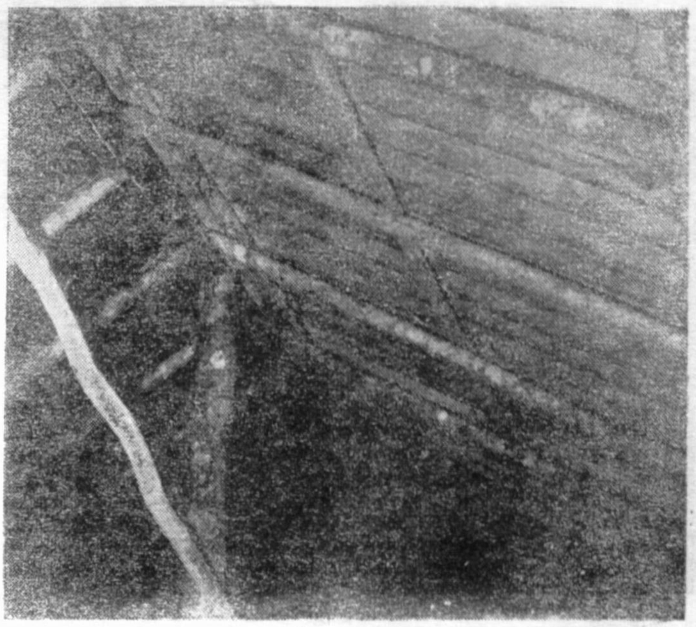

Fig. 3

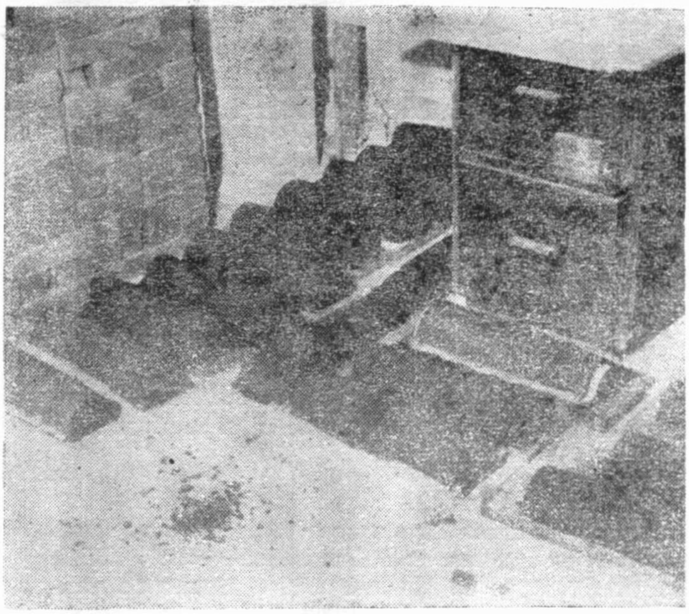

Fig. 2

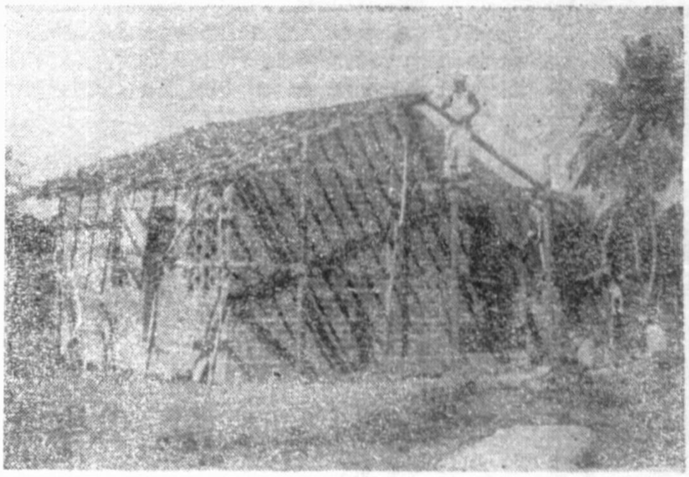

Fig. 4

2.4 Door and Window Frames and Hinges

Rebated wall edges in cement mortar which perform all three functions of a door/window frame –viz. draught exclusion, door/window stop and hinging of door/window sash have been developed as substitutes for costly timber door/window frames. The wall edges could be done simultaneously with wall plastering. The part of wall above the door/window opening can be supported by means of a concrete thin lintel 100 x 75 mm. (4 x 3 in.). The door/window could be hung by means of low cost M.S. pivot hinges or by conventional brass hinges through timber inserts. The entirety of the substitute door/window frame can be built on the site—the mason taking the place of the carpenter. The low-cost door/window frames could yield a cost saving of 50–70%.

2.5 Timber Frame Construction for Very Weak Soils

Very weak soil conditions like marsh and peat are found in many parts of Sri Lanka. For instance, there are 1,000 hectares (2,500 acres) of marshy land in and around Colombo. For traditional construction systems it is necessary to reclaim these marshy swamps, which at present costs about Rs. 70-100/- per m². Even then the traditional constructions on reclaimed land often give rise to foundation problems. The Building Research Institute has developed a timber-frame construction system which does not require land reclamation. The construction system consists of a timber raft foundation, which is placed well below the water level of the peaty swamp, supporting an all-timber house on stilts. The design incorporates simple nailed-joints so that it can be self-built or built on self-help.

Hora or other durable species of timber is used for the raft. The total cost of such a timber frame house is Rs. 5,500/- if built on self-help. At the present prices, the cost of construction on self-help of a traditional house of the same floor area would be Rs. 12,000/- inclusive of land reclamation. The cost saving is over 50%. The present timber-frame construction therefore represents a solution to housing the city's poor. The study already quoted indicates that if built on reduced plot a timber frame house of 21 m² could be built on self-help to reach a large majority of the households in the city (1).

3. Labour-Intensity

The problem of how to measure the intensity of labour has always troubled theorists and concept of labour-intensity still remains ambiguous and ill-defined[2]. In publications on economic development labour intensity is often inferred indirectly from the degree of capital intensity measured in terms of capital-labour or capital-output ratios. Without going into this controversial issue, we shall limit ourselves to measure the labour-intensity of the low cost housing techniques by the labour-output ratio expressed in labour cost in Rupees per unit output. We shall also express the $\frac{\text{labour cost}}{\text{total cost}}$ ratio for the low cost techniques which is also an indicator of labour-intensity. We shall measure the labour-intensity evidently with respect to a self-help exercise. Table I gives these data for the low-cost housing techniques together with the same data for the corresponding conventional construction. It is readily seen from this data that low cost techniques, in as much as they are cheaper, involves a transfer of the production cost of materials to the site costs in the form of labour costs.

For instance soil-cement half brick walls are a third more labour-intensive than the equivalent clay brickwork. For one-brick wallsoil-cement presents a cheaper solutions in its overall costs and the labour intensity measured on labour-output scale is also lower. However on the basis of $\frac{\text{labour cost}}{\text{total cost}}$ ratio it is seen that soil cement block work is almost twice as labour intensive as the conventional one-brick walls.

The figures for floor paving are equally indicative of the labour intensiveness of the low-cost housing techniques. In roofing, the cement half round tiles on concrete rafter system, is over thrice as labour-intensive and the cement half-round tiles on timber pole rafter system twice labour-intensive as the clay tiles on timber scantlings system.

With the low-cost door-window frames the total cost per unit is less than that for the corresponding conventional frames and the $\frac{\text{labour cost}}{\text{total cost}}$ which gives a better indication of the labour-intensity shows that the former are almost twice-labour intensive as the latter.

4. Cost and Labour Intensity Comparison for an Entire House

A house design for low income families of floor area 31 m² (333 ft²) prepared by the Department of National Housing has been studied for the purpose of cost and labour-intensity comparisons. The 31 m² house design (Type L²) is a typical traditional house with brick walls and clay tiles on timber scantlings. The design has been modified while keeping the same architectural features to take the low-cost housing materials and techniques. The Table II below shows the comparative data.

TABLE II

		Traditional Construction	Low-Cost Construction
1	Total cost (if built on hired labour)	Rs 16,000	Rs 12,000
	Cost Saving	—	25%
2	Cost if built on self-help ...	Rs 13,000	Rs 7,500
	Cost Saving	—	40%
3	$\frac{\text{Labour cost}}{\text{Total cost}}$	19%	37%

This data reiterates the cost savings that could be achieved with the low-cost construction (40% on self-help) and shows that a low-cost construction could also be twice as labour-intensive as an equivalent conventional construction.

5. Productivity and Speed of Construction

When the volume of construction to be executed is high, as in the case of housing planned by Government, the speed of construction is also a vital factor and it should be compatible with the objectives set. The speed of construction is intimately tied with the productivity. The Table I shows productivity figures for low-cost housing techniques compared with the corresponding conventional construction. Evidently on the present scale (labour productivity) the low-cost labour-intensive techniques require more labour per unit output. However it does not mean that as a result the speed of construction should suffer.

The speed of construction can be suitably adjusted to required levels by increasing labour strength. Here again the low-cost housing techniques conform with the Government policy that employment generation be given high priority.

Nevertheless it is in this sphere of activity that low-cost housing techniques have surrendered to conventional construction and then to industrialized system building Increased output in labour-intensive production techniques can be achieved by two ways, viz. proper site organization and programming of housing projects, semi-mechanization of production and other on-site jobs. Site organization and modern programming techniques though applicable to a certain extent are often impracticable in a housing site utilizing self-help. Furthermore the modern planning and organization methods are aimed at minimizing the labour unproductive time[3]. It should be stated that it is this very basis which has hampered the application of such techniques in construction in Sri Lanka. The humid tropical climatic conditions prevalent in Sri Lanka require rest time in-between jobs and the concept of unproductive time needs adaptation to those conditions.

A more realistic approach for augmenting output in self-help construction, therefore, appears to be increasing output of the different on-site jobs by semi-mechanization, such as improved hand-operated machines to cast bricks at a faster rate, improved methods of laying bricks etc.

6. House Design and Performance of Low-Cost Housing Materials

The house design for humid tropical climatic conditions within the realm of low-cost poses some basic problems. The difficulties arise largely due to the fact that the low-cost solutions for thermal comfort, acoustic comfort and lighting which rely on natural phenomena are in conflict when applied to a low-cost urban or rural house. The contradictions also appear in low-cost solutions for materials, structural systems and conservation of land.[4] The net effect is that the performance of the low-cost house is impaired, if not diminished. However on this scale of performance there does not appear to exist any difference in the performance between a low-cost house and a traditional clay brick-tiled house, both being equally inefficient in performance.

The measurement of performance of building materials and systems is the subject of intense research activity at the present moment in many parts of the world[5]. Rigorous methods of measurement of performance are yet to be evolved.

However for our purposes, an assessment of the performance of the low cost housing materials and systems and the traditional brick and tile system may be made by comparing the structural strength and stability, thermal transmittance, durability and weathering resistance, fire resistance and health hazards. Table III gives some basic properties of the low-cost materials and those of the conventional bricks and tiles presently available in the market.

TABLE III

		Unit Width Kg/m	Water Absorption in 24 hrs.	Strength	Nominal Dimension
1	Soil-cement block & brick	1800	15-20%	compressive: (2.8–3.5 MPa)	295 x 140 x 90 mm 210 x 100 x 65 mm.
2	Cement-sand brick	1600	5-8%	compressive: 2.8–5 MPa	210 x 100 x 65 mm.
3.	Common clay brick	1200	20-28%	compressive: 2.5–4 MPa	202.5 x 99 x 54 mm. 8 x 4 x 2.1 in.)
4.	Cement half-round tile	2.8 kg per unit	5%	transverse: 80 kg.	450 x 145 x 120 mm.
5.	Half-round tile	2.5 kg per unit	10-15%	transverse: 70-80 kg	385 x 160 x 108 mm.

The soil-cement blocks and cement-sand bricks have higher compressive strength and therefore should perform structurally better than the commonly available clay bricks. Furthermore the low-cost materials could be easily made to yield an even quality which is hardly obtainable with the clay bricks available at present. This observation also applies to the linear format dimensions and regularity of common clay bricks (which vary within a wide range and require thicker mortar joints and larger number of bricks per unit volume (or area) than the low-cost materials).

The soil-cement blocks and cement-sand bricks absorb less water and are denser than the commonly available clay bricks. Therefore the low-cost constructions are more resistant to penetration of dampness than the clay brickwork. In view of the higher unit weight it may be argued that the low-cost constructions would be less thermally comfortable than the equivalent common clay brickwork which has a lower unit weight. However, in a humid tropical environment such as ours, the thermal comfort depends largely on the movement of air than on the thermal properties of the construction materials. The same argument holds for the cement roofing tile since it has the same form as the equivalent clay tile. The denser low-cost constructions, on the other hand, will impart a better acoustic environment than the conventional clay products. The soil-cement constructions are built with soil-cement mortar which is more plastic than the cement mortar presently used in clay brickwork, (lime is rarely used at the present moment for jointing due to its high cost), and therefore soil-cement constructions would be able to accommodate greater differential movement such as those arising from foundation settlement than the common clay brickwork. The fire resistance of both constructions should be comparable. The low-cost constructions and the conventional constructions should be equally hygienic for the occupants.

Laboratory and full-scale exposure tests prove that the durability and weathering resistance of the low-cost housing materials are comparable to those of conventional constructions.

Summary and Conclusions

Among the low-cost housing materials and techniques developed by the Building Research Institute are soil-cement bricks and blocks for walling and floor paving cement half-round tiles, round-pole timber construction, R.C. rafters and plain concrete wall plates for roofing; door/window frames of rebated wall edges in cement mortar and thin concrete lintel and M.S. pivot hinges. They could replace the conventional materials used in housing and building in Sri Lanka. Furthermore a low-cost timber-frame construction system especially suitable for housing construction on very weak soils or peaty swamps has been developed.

The low-cost housing materials and techniques are evidently cheaper than the conventional constructions—soil cement brick-work could save 40-70% in wall construction costs, cement half-round tiles on round-pole timber rafters, 40% in roofing costs, M.S. pivot hinges 60% and low-cost door,window frames 50-70% compared to the equivalent conventional constructions. The timber frame construction which could be built on self-help at half the cost of an equivalent brick-tiled house represents a housing system with which to reach the lowest strata of the urban populations in Sri Lanka.

Cost comparisons for an entire house of traditional design and of 31 m² reveal that savings of the order of 40% on self-help construction could be achieved with the low-cost housing materials and techniques.

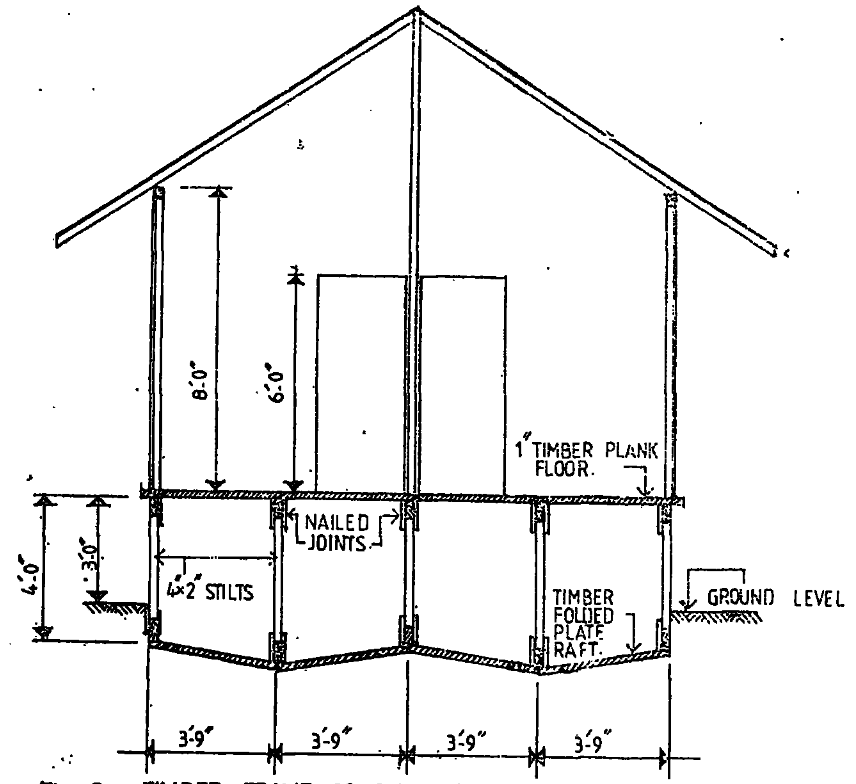

Fig. 5. – TIMBER FRAME CONSTRUCTION FOR VERY WEAK SOILS.

The low-cost constructions are undisputably more labour-intensive in a self-help context and are characterised by a transfer of a part of the production cost of materials to the on-site labour-cost. For instance measured on labour-output ratio soil-cement half brick walls are a third more labour-intensive than the conventional clay half-brick work and cement half-round tiles laid on concrete rafter system is thrice as labour-intensive as the conventional clay round-tiles on timber scantlings.

Productivity measured in terms of man-hours per m² of these low cost housing techniques are evidently lower but desired speed of construction can be achieved by increasing labour strength which has many other beneficial effects. However, higher productivity should be targeted on self-help by semi-mechanization of various on-site production processes and construction methods.

The low-cost housing materials perform more efficiently than the conventional building materials presently produced in Sri Lanka.

Note: This paper is a revised and updated version of a paper bearing the same title read at the National Workshop on Appropriate Construction Technology, May 1979, Colombo.

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