LANDCRETE BLOCKS FOR CONSTRUCTION OF HOUSES

by

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Summary

Suitability of manufacturing and using cement stabilized soil (landcrete) blocks for low cost house construction is presented. Suitability of laterite soils for stabilized blocks can be established by performing three field tests, the Jar test, the Box text and the Drop test. Laterite soils with 15% to 30% are the best for manufacturing landcrete blocks. 2% of cement is adequate for sufficient strength (more than 1.0 N/mm^2) compressive strength) of landcrete blocks. Cement slurry paint is recommended to protect blocks from rain. Cost analysis has proved that landcrete block walls are 40% cheaper than cement:sand block walls.

1.0 Introduction

In low cost houses walls cost more than 25% of the total cost with traditional building materials such as cement sand blocks or burnt bricks. Therefore the use of low cost walls will produce a good low cost house. In the resent past many low cost wall methods have been presented such as 1:12 cement:quarry dust with coir fibre using slip form techniques (Kulasinghe 1989a. 1989b). Industrialize pre-cast concrete walls (Varandarajan 1989), burnt and unburnt bricks walls (Rai and Dave 1991) etc are few examples. Further there are lot of soil related traditional low cost walls such as Wattle and Daub, Cob, Poured Adobe on mud concrete, Adobe bricks, Rammed earth etc. (Department of Housing and Urban Development USA, 1969). However earth related above methods have poor acceptance record by normal Sri Lankan house builders/owners. Almost all the new techniques for low cost houses were implemented in government or NGO (Non Governmental Organization) housing projects (Perera 1992a, 1992b).

Pressure compacted machine made stabilized soil blocks (landcrete blocks) have been used extensively in south and central America, Africa as well as in many other countries (Department of Housing and Urban Development USA 1969, Norton 1986, Winden 1986, Stulz 1983). Compressive strength up to 10 N/mm^2 (1400 lb/in^2) have been recorded, when stabilising admixtures have been used (Department of Housing and Urban Development USA 1969). Lins (1984) have recorded compressive stress between 1.9N/mm^2 to 4.1 N/mm^2 for stabilizing soil using cement percentages 7 to 16. Building Research Institute (now NBRO) has given a method to manufacture soil stabilized blocks; however details are not comprehensive (BRI 1974). Considering these results a research was undertaken to test the suitability of using cement stabilized soil blocks in Sri Lanka.

2.0 Testing Procedure

The objective of the research was to find out a method to produce landcrete (soil stabilized) blocks for low cost house construction in Sri Lanka. Therefore blocks were made using a CINVA ram block press machine and strengths of blocks were established. Field tests were used in the block making process to find out the optimum moisture content, clay percentage and for minimum cement content requirement. Further sieve analyses were done to find out the particle size distribution.

2.1 Field tests for soils

Most of laterite soil is suitable for making blocks, but it must be tested first to find out how much sand, silt and clay it contains. The following tests can be performed in the field to test the suitability of soil and to find out the minimum cement content required (Tool Foundation 1982).

1. Jar test
2. Box test
3. Drop test

Jar test separates the sand from the clay and silt, so the quantity of each can be measured. The test involves filling

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a glass jar half-full with soil (see Fig.1), adding of two teaspoonfuls of normal salt (this makes particles settle faster) and filling full with water. Then shaking or stirring for two minutes and leaving it to settle for several hours. Sand and gravel will settle to the bottom, leaving the silt and clay on top (see Fig. 1). By measuring the height of each layer the total amount of sand and the amount of clay and silt can be computed.

Box test (see Fig. 2) shows the quality of the soil and allows the user to determine the amount of cement that should be used with it. The box for the test should have internal dimensions of 600x40x40 (mm) and should be oiled before used. The testing procedure is compacting soil well especially in the corners and levelling of the top. The box with soil should be sun dried for three days and should be in the shade for the next seven days. It should be protected from rain. Finally shrinkage should be measured after tapping one end of the box on the ground so that all the soil slides down to one end. TOOL Foundation (1982) has recommended soil cement proportions as given in Table 1 while Norton (1986) has recommended proportions given in Table 2.

Drop test was performed to test the moisture content of soil. The test involves taking a handful of soil which is wet enough to form a ball and squeezing in hand and finally dropping from 1m height (see Fig. 3). If ball breaks to a few pieces the quality is good.

2.2 Block Making

The blocks were made using CINVA ram manual machine. The blocks were pressed by 8 tonne nominal force with compression ratio of 1.5.1. The standard block size was 300x140x120 (mm). The details of manufacturing of the machine and relevant information are given by (ATI 1990). The process of block making is shown in Fig. 4.

2.3 Compressive Strength test

Compression strength of blocks perpendicular to the compression face were tested for 7 days and 28 days. Blocks were made for cement percentages by weight for 0%, 2%, 4%, 6%, 8%, 10%, 15%, and 20%. The compressive strength test was held according to the method given in SLS 39. A total of six soil samples from different parts of Sri Lanka were tested.

2.4 Sieve Analysis of Soil

Sieve analysis according to BS1377:1975 was done for all six samples to find out the true particle size distribution and to check the accuracy of the Jar test (field test).

2.5 Weathering Test

Weathering test for blocks was done according to ASTM D 559:1982. The objective of the test was to find out the performance of blocks for wetting and drying and to find out the minimum cement percentage required to resist weathering (ie wetting and drying). The test involves making cement:soil cylinders from a mould 100mm(dia) x 63.5mm(height). The samples were made using mechanical rammer, which is normally used for optimum moisture content test. the samples were first dried at a temperature of 110^0C. Thereafter samples were immersed in water for 5hr. and subsequently dried at a temperature of 71^0C for 42 hr. Wetting and drying were continued for 12 cycles and the weight loss after 12 cycles was measured.

A weathering test by measuring the resistance to water erosion has been proposed by Norton (1986). In this test water is sprayed on the face of stabilised block using a 100mm diameter shower head at a distance of 180mm from the surface with a pressure of 1.4kg/cm^2. After spraying pitting on the surface is measured and interpreted as follows.

1. Pitting 6-12mm is acceptable for use in areas with 50 mm to 500 mm rainfall per annum

2. Pitting 0-5mm is acceptable for use in areas with 500 mm to 1250 mm rainfall per annum.

3. In areas with rainfall higher than 1250 mm per annum there should be no pitting.

3.0 Results of tests

3.1 Tests for particle size distribution

Particle size distribution based on sieve analysis results and of the Jar test are shown in Table 3. Results show that the Jar test which is a very simple field test can give sufficiently accurate results for particle size distribution.

3.2 Compressive Strength

3.2.1 Dry Compressive Strength

Compressive strength of blocks at 7 days and 28 days are shown in Table 4 and Table 5 respectively for different cement percentages (by weight). Further Fig. 5 shows how strength varies with cement content and clay content. According to SLS 855:1989 (Sri Lanka Standard for Cement Blocks) compressive blocks compressive strength required for single storey is 1.2 N/mm^2. However according to Department of Housing and Urban

Table 1 Winden's Soil:Cement Proportions

Box test Shrinkage	Mix by volume Cement:Soil
0 - 10	1:35
10 - 20	1:30
20 - 30	1:25
30 - 40	1:20
40 - 50	1:15

Table 2 Norton's Soil:Cement Proportions

Box test Shrinkage	Mix by volume Cement:Soil
0 - 12	1:18
12 - 24	1:16
24 - 39	1:14
40 - 50	1:12

Table 3 Results of sieve Analysis and Jar Test

Sample No.	Sieve Analysis Percentage of		Jar Test Percentage of		Error in Jar test
	Clay and Silt	Sand & Gravel	Clay and Silt	Sand &Gravel	Clay & Silt %
1	24.2	75.7	27.3	72.7	-3.0
2	29.6	70.4	35.2	64.8	-5.6
3	9.10	90.9	18.4	81.6	-9.3
4	19.8	80.2	25.3	74.7	-5.5
5	39.0	61.0	45.5	54.5	-6.5
6	15.3	84.7	19.9	80.1	-4.6

Table 4 7day Compressive Strength of Landcrete Blocks

Cement Percentage	Soil Sample Number 1	2	3	4	5	6	Average Compressive stress N/mm²
	Compressive Stress N/mm²						
0	0.87	0.97	0.08	0.94	0.28	0.75	0.65
2	-	1.40	0.16	1.40	0.38	0.88	0.85
4	-	1.86	0.76	1.80	0.50	1.12	1.21
6	-	2.40	1.40	1.90	0.78	1.50	1.60
8	-	1.88	1.66	1.70	0.88	2.70	1.76
10	-	1.96	1.81	3.10	0.95	2.84	2.13
15	-	-	1.45	3.62	1.10	3.70	2.47
20	-	-	2.97	4.83	1.13	4.35	3.32

Table 5 28day dry Compressive Strength of Landcrete Blocks

Cement Percentage	Soil Sample Number 1	2	3	4	5	6	Average Compressive stress N/mm²
	Compressive stress N/mm²						
0	-	0.83	0.55	1.00	0.75	0.88	0.80
2	1.69	1.80	0.75	1.40	1.00	1.20	1.31
4	3.07	2.38	0.83	2.42	1.50	1.70	1.98
6	3.29	3.75	2.00	3.25	2.00	2.10	2.73
8	2.68	3.87	2.90	3.95	2.40	3.40	3.20
10	-	4.25	3.50	4.20	2.30	4.00	3.65
15	-	-	3.90	5.70	2.40	5.40	4.35
20	-	-	4.20	6.60	3.30	7.90	5.50

Table 6 28day Wet compressive strength and water absorption of Landcrete Blocks

Cement Percentage	Soil Sample Number 4	5	6	Average Compressive stress N/mm²
	Compressive Stress N/mm²			
0	*	*	*	*
2	*	0.40	0.23	0.32
4	0.26	0.65	0.55	0.49
6	0.34	1.10	0.83	0.76
8	0.78	1.80	1.30	1.29
10	1.30	1.95	1.85	1.70
15	1.40	2.10	2.30	1.93
20	1.70	3.40	3.00	2.70

* Dissolved in water

Development USA (1969) the minimum compressive strength required for blocks in walls is 0.68N/mm^2 (100 pounds/in^2) Fig. 5 clearly shows that 0.68 N/mm^2 compressive strength could be achieved with soils except soil sample No. 3 without any cement added. Further Table 5 shows that except for soil samples No. 3 and No. 5 other soils satisfy SLS 855 requirement with 2% cement. There is a significant increase in strength from 0% of cement to 2% of cement. However this increase is much less for further increases in cement content. Considering the minimum requirement of 0.68 N/mm^2 2% of cement can be considered as the best for the manufacturing of landcrete blocks for Sri Lanka's laterite soils. It is clear from Fig 5 that the compressive strength is optimum when clay percentage is in the region of 15% and 30%.

3.2.2 Wet Compressive Strength

Table 6 shows the compressive strength of blocks after soaking in water for minimum of 96 hours. The compressive strength drops substantially however if the clay percentage is in the optimum range: ie. clay content is between 15% and 30%; the minimum required strength (0.68 N/mm^2) can be achieved by addition of 6% cement. To satisfy the SLS 885 requirements at least 6% cement content is required. Fig. 6 shows how the wet compressive strength varies with clay content for different cement contents.

It is clear from Fig 6 that if flooding is a possibility then a minimum of 6% cement content should be used to manufacture landcrete blocks.

3.2.3 Box Tests & Cement Content

Box test was held for four soil samples. Considering the minimum required dry compressive strength of 0.68N/mm^2, Table 7 shows required minimum mix proportions. Table 7 proves that box test gives a good indicator for cement soil mix proportions.

3.2.4 Block Soil Density and Compressive strength

Block dry density give a measurement of compaction. Soils with dry compacted density less than 1650 kg/m^3 are not suitable for soil stabilized blocks (Spence & Cook 1983). Fig. 7 shows the dry density and compressive strength and all soils have achieved a dry density more than 1650kg/m^3 except solid sample No. 5 (clay 39%).

3.3 Water absorption

Water absorption of blocks was measured and results are given in Table 8. The maximum water absorption allowed in Sri Lanka Standard 39 (SLS 39) for bricks is 28% for Type II and 18% for Type 1. The results of Table 8 show that soil stabilized blocks satisfy the requirements of Type I bricks.

3.4 Weathering Test

Two types of weathering tests were done as discussed in section 2.5 of this Paper. No pitting was observed with blocks with cement slurry paint on sides. However a minimum of 8.5 mm pitting was observed in 2% cement soil stabilized blocks. Therefore blocks should be given a protective coating.

The weathering test according to ASTM D559:1982 gave mixed results. Higher cement percentages indicated high weight loss, indicating some error in testing. This needs careful investigation in the future.

4.0 Cost

A material to be effective it should be available and should be able to produce at a reasonable cost. Furthermore a material such as soil stabilized blocks to be effective for house construction should be cheaper than bricks and cement sand blocks.

4.1 Cost of cement stabilized blocks

The main cost components are cement, labour and soil (if purchased).

4.1.1 Cost of Cement

The cost of cement depends on the cement percentage used. Further if sides are painted with cement/water paint it needs approximately 25g of cement per face. Average density of blocks is around 1950kg/m^3. Considering above, cost of cement will be as given in Table 9 (Cement bag priced at Rs. 220/-).

In a practical application of the construction of a boundary wall and an extension to a house in Piliyandala it was found that 2% cement stabilization was more than adequate (with more than 0.7N/mm^2 strength). In the practical applications more than 200 blocks were made with one bag of cement.

4.1.2 Cost of Labour for stabilized blocks

In the practical application two people were able to make approximately 200 blocks per day (both sides painted). Widen et al.(1986) has recorded that optimum gang of four men can produce 300 blocks per day. Any unskilled person can make soil stabilized blocks and considering a rate of Rs. 100/- per day person, cost of labour will be as given below.

Table 7 Box test results and minimum cement content

Clay %	Box test result mm	Minimum cement % required	Mix proportions with minimum cement Cement:Soil
9.1	1.5	2	1:35
15.3	0.8	0	1:35
19.6	1.7	0	1:35
29.6	2.0	0	1:35

Table 8 Water absorption of landcrete Blocks

Cement Percentage	Soil Sample Number 4 water Absorption	5	6	Average water Absorption %
0	*	*	*	*
2	*	3.10	6.11	4.61
4	5.50	3.88	6.88	5.42
6	7.58	4.95	5.45	5.99
8	6.42	4.00	4.27	4.90
10	5.08	3.26	3.60	3.98
15	5.36	3.94	4.55	4.61
20	4.95	4.93	3.42	4.43

* Dissolved in water

Table 9 Cost of Cement for stabilized blocks

Percentage of cement	Cost per block in Rs. without sides painted	One side painted	Two sides painted
0	0	0.11	0.22
2	0.87	0.98	1.09
3	1.30	1.41	1.52
4	1.73	1.84	1.92
5	2.16	2.27	2.38
6	2.59	2.70	2.81
8	3.46	3.57	3.68
10	4.32	4.43	4.54

Table 10 Cost of 2% cement stabilized block walls

Type of project	Cost of soil cement block wall Rs/sqr. Without sides painted	one side painted	Two sides painted
1. Self help schemes user made blocks paid skill labour	530	552	576
2. Low cost housing schemes with all paid labour	796	818	842

Cost of 4 men gang = Rs. 400 per day
Number of blocks per day = 300
Cost of labour per block = Rs. 1.33

4.1.3 Cost of soil for blocks

In the case of rural housing the soil can be obtained from the site itself. However in city applications soil needs to be brought in. In the practical application approximately 300 blocks user made with tractor load, was purchased for Rs. 275.00. Therefore cost of soil can be stated as Rs. 1.00 per block approximately.

4.2 Cost of landcrete block walls

In the practical applications one skilled mason and one unskilled labour were able to complete 2 sqrs. (approximately 400 blocks) in one day. The following were used for 1sqr. of blockwork.

1.25 bags of cement = Rs. 275
11ft^3 OF SAND = Rs. 71.50
Total mortar cost = Rs.346.50
0.5 day unskilled labour = Rs. 90.00
0.5 day skilled labour = Rs. 50.00
Total cost of labour = Rs. 140.00
Cost of stabilized blocks(2% cement) = Rs. 1.10 + 1.33 + 1.00
= Rs. 3.43
200 blocks per sqr = Rs. 200x3.43
= Rs. 486.00

Total cost of block work per square = Rs. 346.50 + 140 + 486.00
= Rs. 972.50

However in many applications soil will be free of charge and in self help housing projects users could make the stabilized blocks for their houses. Table 10 gives the cost stabilized blocks in self help low cost housing projects. These blocks are made with 2% cement content.

Considering current prices of cement sand block work (4" thick) cost of 1sqr. of cement sand blockwork is around Rs. 1430/- (all paid labour). Therefore cement stabilized blocks are 41% cheaper than cement:sand blocks.

5.0 Conclusions

Considering the test results and available literature the following conclusions can be made.

1. Cement stabilized laterite blocks can be manufactures with required strength, durability, appearance and other normal requirements.

2. 2% cement content is adequate for normal single storey house construction.

3. Simple field tests - the Jar test, the Box test and the Drop test can give satisfactory controls for the manufacture of cement stabilized soil blocks.

4. The best soils for manufacture of cement stabilized soil blocks are soils which contain 15% to 30% of clay and silt.

5. Cement slurry paint can provide cost effective and adequate protection against weathering.

6. Good compacted landcrete blocks is be made by using manual CINVA ram machine.

7. The cost of cement stabilized blocks are approximately Rs. 975/50 per sqr and 41% cheaper than cement sand block walls.

6.0 Recommendations and future research

1. It is recommended to use cement stabilized soil (landcrete) blocks for single storey building construction.

2. 2% cement content is adequate for the manufacture of landcrete blocks.

3. Painting sides with cement slurry is recommended for durability.

4. Effects of different curing conditions on strength, further investigations on weathering tests and the use of other soil stabilizers such as lime, bitumen, latex etc, should be carried out.

7.0 Acknowledgements

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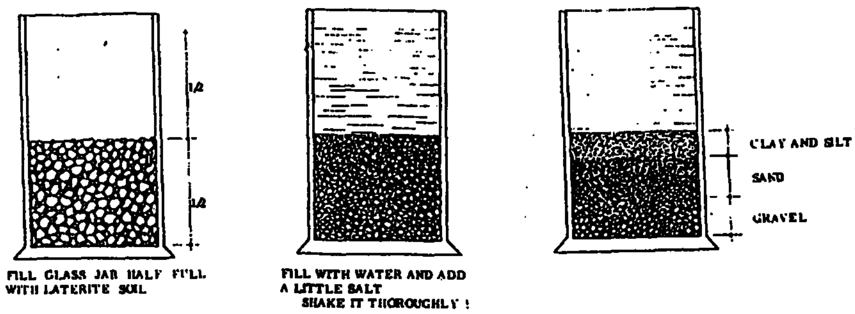


Fig.1 The Jar Test

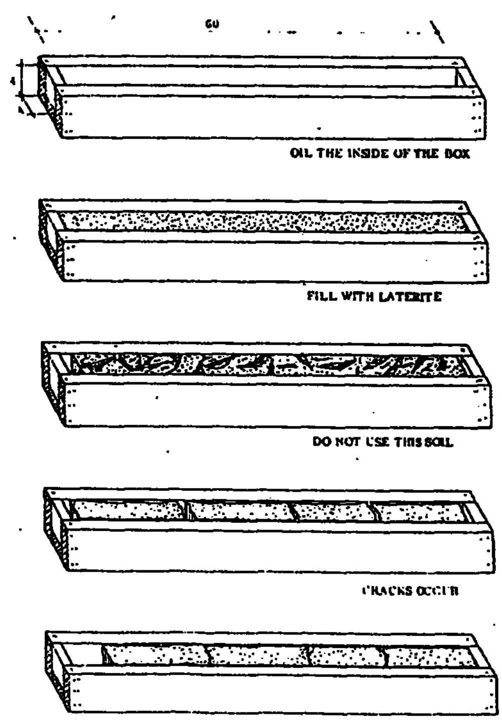


Fig. 2 The Box Test

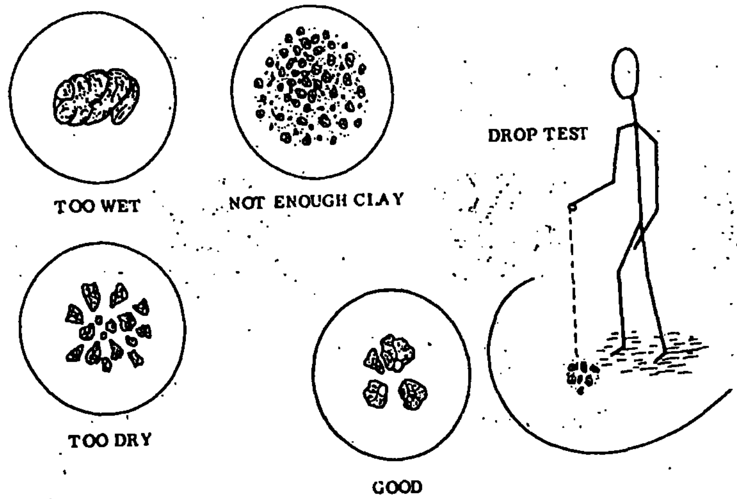


Fig.3 The Drop Test

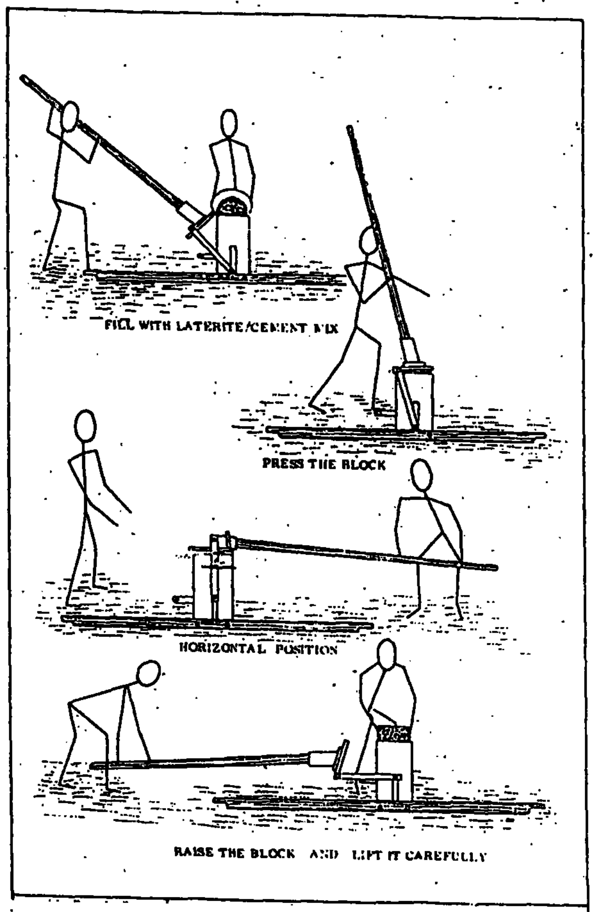
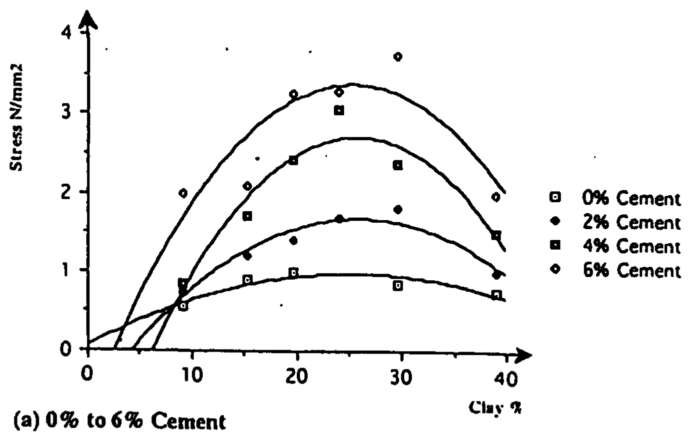
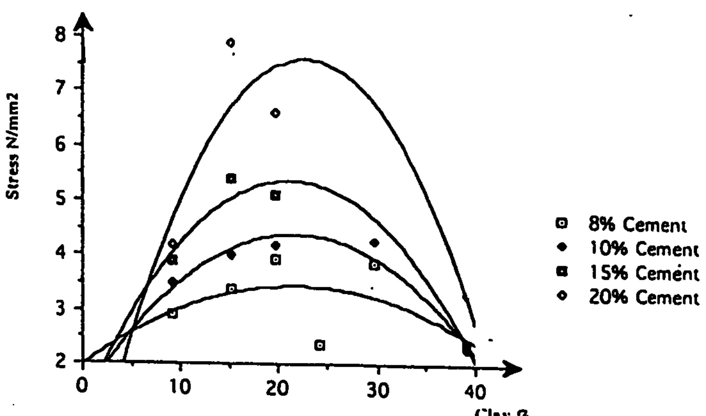


Fig.4 The Process of Block Making



(a) 0% to 6% Cement



(b) 8% to 20% Cement

Fig.5 Compressive Stress Vs. Clay Content and Cement Content.

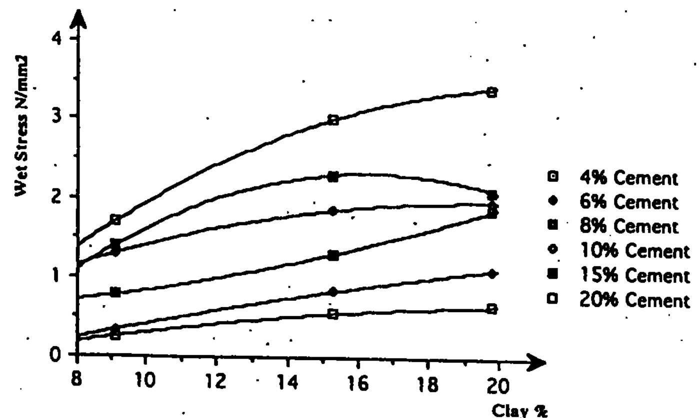


Fig.6 Wet Compressive stress Vs. Clay content and Cement Content

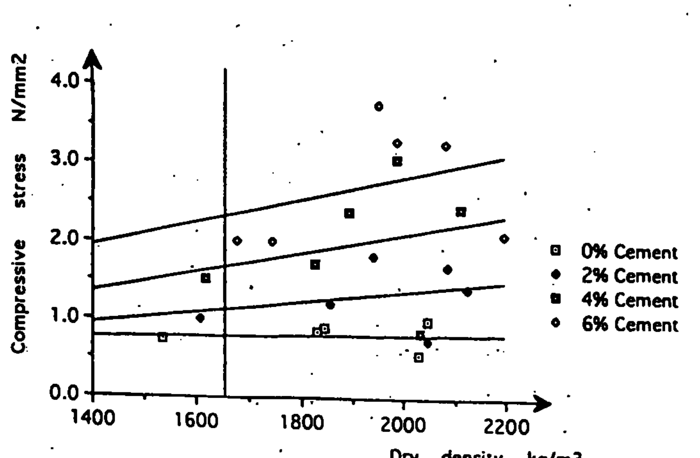


Fig.7 Compressive strength Vs. Dry density