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PRESSED SOIL-CEMENT BLOCK: AN ALTERNATIVE BUILDING MATERIAL FOR MASONRY

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Abstract: The paper deals with certain details of pressed soil-cement block technology. Earlier developments in soil-cement block technology for building construction have been discussed briefly. Principles of soil block production, certain details of block presses, strength and durability aspects of soil-cement blocks have been highlighted. Energy and environmental issues of this technology have also been discussed briefly.

Introduction

Soil is the most commonly available material. It is the basic material for the production of bricks. Burnt brick has been considered as a satisfactory material for masonry construction. They are produced by employing a burning process and hence consume considerable amount of thermal energy during production. Also, very often they are transported over great distances. Pressed soil-cement block is an alternative to burnt bricks. These blocks can be produced in a decentralised fashion employing simple manually operated or semi-mechanized presses utilising local soil. Also, these blocks are economical and consume less thermal energy during production. This paper focuses on the details of pressed soil-cement block technology, emphasizing the Indian experience in this technology.

History and development of soil-cement construction

Soil-cement has been successfully used for the construction of roads and air field pavements in different parts of the world. However, use of soil-cement for building construction has had an erratic history. Soil-cement rammed earth walls were used for the construction of 4000 houses in Karnal (Haryana, India) during 1948 (Verma and Mehra, 1950). This perhaps is one of the earliest examples of soil-cement construction for housing. Hand made soil-cement blocks were used for the construction of 260 houses in Bangalore, India, during 1949 (Madhavan and Rao, 1949). After these early experiments, use of soil-cement for building construction in India became rather infrequent.

The concept of pressed soil-cement block for masonry construction came into practice after the development of CINVA-Ram press in 1952. Houses constructed using soil-cement blocks prepared using this machine came up in Columbia, Chile, Venezuela, Bolivia and Brazil (U.N., 1964). Soil-cement has been used for house construction in the sixties and seventies in Zambia, Lusaka, Thailand and Ivory coast (UNCHS, 1984, Ph. Theunissen, 1985). Pressed earth blocks were used for the construction of a huge housing project in Australia. About 6 million blocks were produced and used for the project (Worthing et al, 1992). Also, at present soil-cement block houses are common in Australia. The formation of CRATERRE group (Centre de Recherche et D' application - Terre, Grenoble, France) in the seventies is responsible for the construction of a number of soil-cement block buildings in Africa and Europe. Centre for the Application of Science and Technology to Rural Areas (ASTRA) and the Dept. of Civil Engineering at the Indian

Institute of Science, have been involved in the R&D, dissemination and construction of soil-cement block buildings since 1976. Their efforts have resulted in a steady increase in the soil-cement block users (Jagadish, 1988), and now there are more than 2000 soil-cement block buildings in Bangalore city and surroundings.

Soil block presses

A variety of soil block presses are available in the global market (Mukerji, 1986). Soil block presses can be grouped into 3 types, Viz., (1) Manually operated, (2) Semi-mechanized and (3) Highly mechanized presses. Highly mechanized presses are generally suitable for centralized production in the form of big industries. Manually operated and semi-mechanized presses can be transported easily and hence, are suitable for decentralized production.

Majority of the soil block presses employ static compaction process. In this process, loose soil is compressed in a mould through the movement of a piston. Figure 1 illustrates the process of compaction for pressed soil block production. The principles of static compaction of soils, especially for soil block production have been investigated in detail by Reddy and Jagadish (1993).

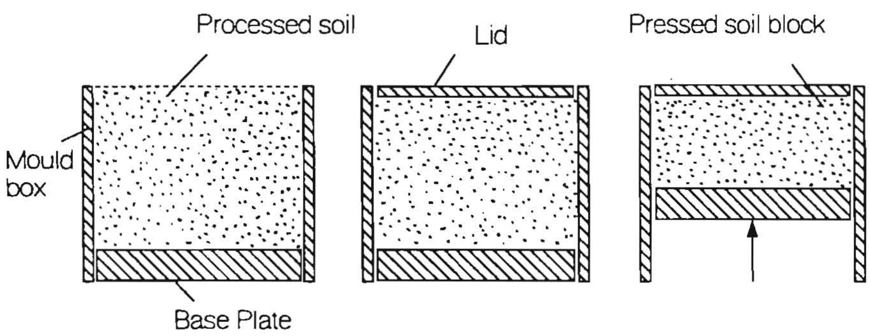

Figure 1. The process of compaction for pressed soil block production: (a) mould filled with processed soil (b) compaction at top due to lid closure (c) compaction at bottom due to piston stroke

Specifications of some of the soil block machines available in the global market can be find in the Mukerji's report (1986). Based on the details of this report and authors experience in design and use of soil block machines, the following observations can be made.

(a) Manually operated machines are light weight and easy to transport, with a daily production of about 300 - 500 blocks. The compaction pressures will be in the range of 1.5 to 3 Mpa.

(b) The area of the block (breadth X length) should be restricted to less than 45,000 mm^2, in view of the limited energy supplied by persons involved in compaction operations. Any attempt to compact bigger soil blocks in manually operated presses will lead to poor quality blocks, because of low densities due to inadequate compaction.

(c) Mechanized machines can generate higher compaction pressures (6 to 10 MPa) leading to high density blocks, but require skilled persons for operation and maintenance. Also, the overhead costs will be high for mechanized machines.

Production of pressed soil-cement blocks

Three distinct operations can be recognised in the process of soil-cement block production using manually operated machines. They are (a) soil preparation (b) block pressing, and (c) stacking and curing.

(a) Soil preparation

Soil is sieved through 5mm sieve in order to remove bigger clay lumps, gravel etc. Sieved soil is spread into a thin layer on level ground and then the cement is spread on top and mixed thoroughly using a spade. Now water is sprinkled on the dry soil-cement mixture and mixed manually, such that the water gets dispersed uniformly. The wetted soil-cement mixture is pressed into a block using the machine.

Soil preparation has to be carried out in batches such that the wetted soil-cement mixture should be converted into blocks within 40 minutes. This is mainly to avoid setting of the cement before pressing into a block. Generally, soil sufficient for 25 blocks is processed in each batch.

(b) Block pressing

The processed soil is compacted into a block using a machine. This operation consists of the following activities: (a) Feeding the processed soil into the mould, (b) block compaction and (c) block ejection. Figures 2 to 4 illustrate these three operations involved in block pressing.

(c) Stacking and Curing

The blocks can be stacked one above the other upto 6 layers. Close stacking without any gaps will be useful in preventing the drying of blocks while curing. The stack covered with straw on top has to be kept moist by sprinkling water for 3 to 4 times daily for 3 weeks.

Figure 2. Feeding the processed soil into the mould

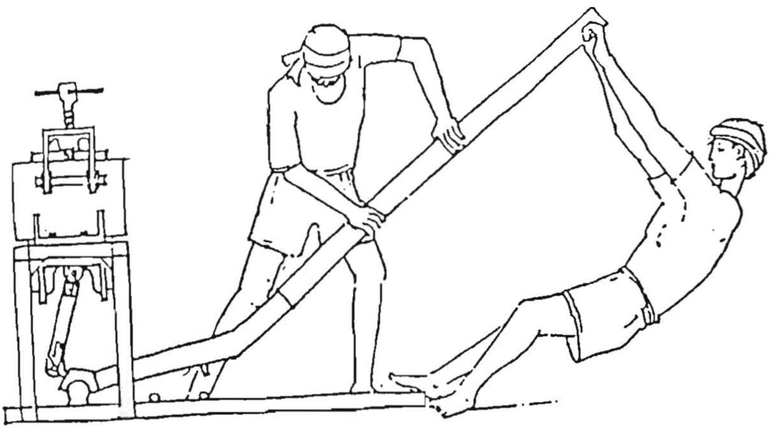

Figure 3. Compacting the block

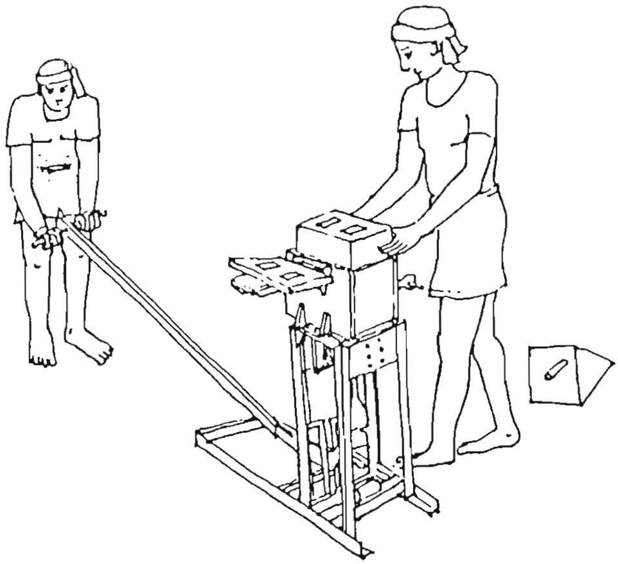

Figure 4. Ejecting the block

Characteristics of Soil-Cement Blocks

Strength and performance characteristics of soil-cement blocks will depend mainly on (a) Block density, (b) Percentage of cement, and (c) Soil composition.

(a) Block density

Density of the block has significant influence on compressive strength. Effect of block density on compressive strength of soil-cement cubes is given in Table 1. The results given in the table are obtained by testing pressed soil-cement cubes of size 76mm. The results clearly indicate that the wet strength is sensitive to density. There is a doubling of strength for a change in density from 17.1 to 18.6 KN/m^3. These results are for a particular soil with 5% portland cement by weight. Similar trend can be observed for other soils and different cement percentages.

Dry density of >18 KN/m^3 can be easily achieved for soil-cement blocks using manually operated machines. The density has to be controlled during block making operations. Density can be easily controlled by resorting to weigh batching in the field production.

Table 1. Effect of block density on strength

Specimen size: 76mm cube, cement: 5% by weight

Dry density (KN/m^3)	21 days wet compressive strength (MPa)
17.06	1.00
17.76	1.44
18.25	1.83
18.64	2.00
18.83	2.35

(b) Percentage of cement

Soils containing predominantly non-expansive clay minerals such as kaolinite, can be easily stabilized with cement. Table 2 gives details of test results conducted on pressed soil-cement cubes prepared using a local soil with 65% sand, 18% silt, and 17% clay size fractions. The results shown in the table indicate that wet strength increases with increase in cement content. There is doubling of compressive strength when the cement percentage is doubled from 5 to 10%. The magnitude of the strength values can vary from soil to soil depending upon their characteristics.

Table 2. Effect of cement content on strength

Specimen size: 76mm cube (source: Reddy, 1988)

Cement content %, by weight	Dry density (KN/m^3)	21 days wet compressive strength (MPa)
2.5	18.35	0.78
5.0	18.54	2.91
7.5	18.44	4.63
10.0	18.74	5.82

(c) Soil composition

Soil contains mainly gravel, sand, silt and clay size fractions. Percentage of these fractions and the clay mineral type, will have a strong influence on strength and durability characteristics of soil-cement blocks. Generally, soils with predominantly non-expansive clay minerals such as kaolinite, are suitable for cement stabilized blocks. Soils with expansive clay minerals such as montmorillonite are difficult to stabilize with cement alone.

Effect of soil composition on strength and durability of soil-cement blocks has been studied in detail by Reddy (1991). Some of the results of this study are given in Table 3. The table gives details of soil composition, wet compressive strength and density for 2 different local soils designated as BGL soil and SH soil. These two soils contain predominantly kaolinitic clay mineral. The results reported in the table were obtained through the testing of 76mm size pressed soil-cement cubes. The natural soil composition has been varied by the process of reconstitution using sand addition.

Table 3. Effect of sand and clay fractions on strength

Specimen size: 76mm cube, Cement: 5%, (source: Reddy, 1991)

Sl. No.	Soil details	Composition (%, by weight), USC system			21 days Wet strength	Dry density KN/m^3
		Sand	Silt	Clay	MPa	
1	BGL soil	48.8	22.4	28.8	0.77	1.82
	BGL soil + 50% sand	65.9	14.9	19.2	2.91	1.86
	BGL soil + 100% sand	74.4	11.2	14.4	3.10	1.89
2	SH soil	39.5	33.5	27.0	1.40	1.81
	SH soil + 50% sand	59.7	22.3	18.0	1.50	1.86
	SH soil + 100% sand	69.8	16.7	13.5	1.41	1.88

The results of the table clearly indicate that the wet compressive strength increases as the sand content increases for the BGL soil. There is a four fold increase in strength as the sand content is changed from 48.8 to 74.4%. As the sand content increases there will be proportionate decrease in clay content of the soil. In case of SH soil there is only a marginal variation in wet compressive strength as the sand content of the soil is increased.

It is to be noted here that both the soils belong to the class CL in Unified soil classification (USC) system and both are fine grained soils. Increasing the sand content of these soils beyond 50% by adding extra amount of sand will make the soils belong to class SC in USC. Eventhough, both the soils belong to the same class in USC system, their response to cement stabilization is quite different. Similar observations have been made by Reddy(1991) for a number other local soils. Some of his major observations are as follows.

(a) Increasing the sand content of the soil generally leads to increase in wet compressive strength. The increase will be significant for some soils.

(b) The strength increases, when they occur, bear no relation to the quantum of sand added.

(c) It can be suggested that in general, a sand content of 60 to 70% and clay content of <15% (non-expansive type) may be desirable for pressed soil-cement block production. These recommendations do not hold good for soils containing significant amount of montmorillonitic type of clay mineral.

His studies also indicate that there is no definite relationship between Atterberg's limits and wet compressive strength of soil-cement blocks. Soils with a L.L. of <40% and P.I. of <19% are suitable for soil-cement blocks.

Durability of soil-cement blocks

The performance of soil-cement blocks subjected to alternate wetting and drying can indicate the durability of the blocks in the long run. Alternate wetting and drying test consists of monitoring the weight loss of soil-cement blocks subjected to wetting and partial drying cycles. The following observations have been made by Reddy (1991) based on the results of 12 cycles of alternate wetting and drying test conducted on soil-cement blocks.

(a) Soil-cement blocks prepared using fine grained soils with high clay fractions, will deteriorate during wetting and drying cycles. These blocks may posses adequate wet strength initially.

(b) Reconstitution of fine grained soils by adding sand will improve the wet strength of soil-cement blocks as well as dimensional stability against alternate wetting and drying.

It is now clear that reconstitution of some soils by sand addition might not improve the wet strength significantly, but the durability characteristics of the blocks will be improved.

Energy consumption and Environmental issues

Energy efficient, economical, and environmentally sound building technologies are essential for sustainable construction practices. Studies conducted by Jagadish (1979) have shown that 5000 Kgs. of wood is burnt in producing bricks sufficient for a 50 m^2 house. Massive housing programmes based on energy intensive materials such as bricks will lead to intolerable pressures on the energy resources such as wood and coal. Considerable amount of energy can be saved by using pressed soil-cement block in place of burnt brick. Table 4 gives a comparison of the energy consumption in burnt bricks and soil-cement blocks. Here an energy of 5.85 MJ/kg of cement has been considered for calculation. The table clearly shows that soil-cement blocks consume only 25 - 30% of the energy used for brick production.

Table 4. Energy comparison in bricks and soil-cement blocks

Sl. No.	Type of Unit	Size (mm)	Energy per unit (MJ)	Energy per m^3 of units
1	Burnt brick	230 X 108 X 75	3.8 - 4.5	2228
2	Soil-cement block (5% cement)	230 X 190 X 100	2.34	536
3	Soil-cement block (7% cement)	230 X 190 X 100	3.28	750

Concluding remarks

Certain aspects of soil-cement block technology have been discussed. The following points are clear regarding the soil-cement block technology.

(a) There is a steady progress in the use of soil-cement blocks for building construction in several parts of the world. Pressed soil-cement blocks can be produced in a decentralized manner utilising local soils and local labour.

(b) The strength and durability characteristics of soil-cement blocks mainly depends upon soil composition, block density and cement content. Soils containing predominantly non-expansive clay minerals with 60 - 70% sand, and <15% clay size fractions are ideally suited for soil-cement block production.

(c) Soil-cement blocks are energy efficient compared to conventional materials such as burnt bricks. They consume only 25 - 30% energy used for the production of burnt bricks. Hence, wide use of soil-cement blocks can lead to considerable savings in energy resources.

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