Lime Stabilized Soil as a Building Material—Preliminary Investigations

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INTRODUCTION

Since the earliest times soil has been a basic material of construction. Even now it is the most widely used material for houses and huts in the country side of the tropics in which floors and walls are exclusively made with mud and the soil is also used in roofs. The drawback with these shelters is the poor resistance to water resulting in its reduced durability, frequent repair or complete reerection of walls and roofs etc. after each spell of rains. Certain amount of resistance to erosion of the soil has generally been achieved through the local practices of the use of such additives as natural oils, juices of some trees, animal dung etc., in the villages, but the improvement in the life of the construction is not much.

In order to achieve a reasonable life of a mud construction, certain attempts have been made in the last two decades by the application of the principles of stabilization to the soil intended for use in the construction. Some experimental houses using soil-cement were put up[1,2]. A big project of this type was taken up in India in which four thousand soil-cement houses were made at several places in Punjab to accommodate displaced persons from West Pakistan[3]. Study of lime, however, has not received any attention for improving the durability of mud houses although it has convincingly proved its promise as a successful stabiliser of soil for roads etc. An attempt has been made here in this direction in which three alluvial soils have been examined by using lime as stabilizer primarily for making stabilized soils bricks.

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MATERIALS

Soils: Three types of soils were investigated. All the soils are illitic and were obtained from places around Roorkee. The following are some of the physical properties of the soils:

Soil Type	S-1	S-2	S-3
Clay content, %	8·35	20·5	17·8
Silt content, %	13·95	31·0	52·8
Sand content, %	77·70	48·5	30·3
Liquid limit, %	20·2	39·6	71·2
Plastic limit, %	15·5	28·3	34·4
Plastic Index, %	4·7	11·3	36·8

Lime: The lime used was freshly hydrated lime belonging to class C as per IS: 712—1973 containing 23% water and 83% calcium oxide on dry weight basis.

EXPERIMENTAL PROCEDURES & TESTING METHODS

Determination of Optimum Moisture Content

For each mix of the soil with and without lime optimum moisture contain (o. m. c.) was determined from the mix water relationship curves drawn as per standard compaction method[4]. Jodhpur mini-compactor was employed in these experiments.

Preparation of Mixes & Specimens

Lime was dry mixed with soil in a mixer. Requisite quantity of water was added in every composition in small amounts at a time with continuous mixing. The following three types of specimens were made.

(a) *Cylindrical Specimens* Laboratory specimens of 5 cm diameter and 10 cm high were made under near Proctor's compactive effort at o. m. c.

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(b) *Full size bricks in hand operated brick press* The bricks are made in the CBRI hand operated brick making machine at a pressure of about 25 kg/cm². The dimensions of the brick are 24.5 cm × 10 cm × 8 cm.

(c) *Full size brick in power press* These specimens were made first in the CBRI had operated brick press and then pressed in an electrically operated brick press which is generally used for making refractory bricks. The estimated maximum pressure obtainable from it is around 80 kg/cm². The size of the brick mould is 25 cm × 11 cm × 7 cm.

In the case of full size bricks water added was 2% more than the optimum, since the casting and curing was done in summer. The specimens were cured in humid conditions under moist gunny bags. The approximate temperature of curing was 28-30°C. The tests were carried out after 14 days and 28 days of curing and also after completing 12 wetting and drying cycles.

Determination of Compressive Strength, Water Absorption dry bulk density etc.

Compressive strength of both dry and saturated specimens was determined (Tables I and II). For the determination of wet compressive strength the specimens were dried in oven at 70°C immediately after the completion of the requisite curing period. These were kept immersed in water for 24 hours before testing. Dry bulk density was determined by weighing dry specimens before putting them in water. Water absorption was calculated from the weight of the saturated specimen just before putting it to compressive strength compression test. Similarly the linear measurements of shrinkage and moisture movement were made on the marks put on the specimen immediately after casting and before and after immersion in water.

Durability Tests

Accelerated weathering tests were carried out on cylindrical specimens as per IS: 1725—1960[5].

Brick panels of two soil-lime compositions (soils S—1 and S—2) were put up in the open at Roorkee for natural weathering (Fig. 1 & 2). The following are the details of the brick panels.

	Panel A	Panel D
Soil	S-2	S-1
Lime (%, by wt)	5	8
Press	Power press	HOP
Mortar for jointing	1:2:9 (cement : lime : sand)	Brick Mix + 10% cement

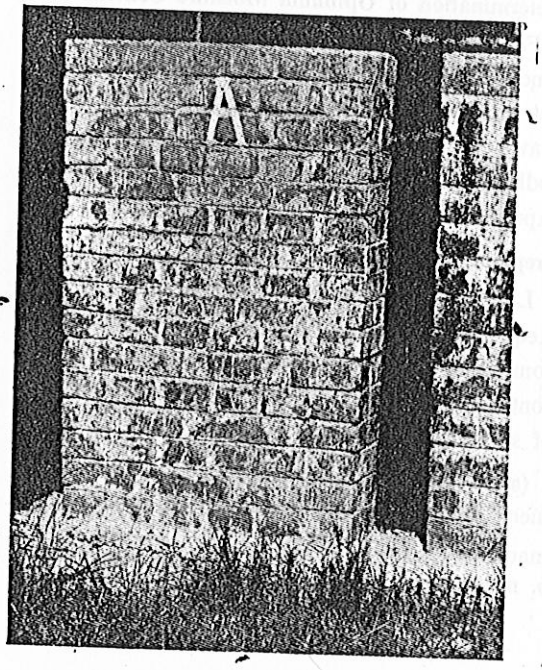

Fig. 1

Fig. 2

RESULTS AND DISCUSSIONS

Optimum Moisture Content

The following are the values of the o. m. c. of various soil-lime compositions.

Mix	Optimum Moisture Content, %		
	S-1	S-2	S-3
Soil only . .	10·5	15·1	29·5
Soil+Lime 3% .	11·2	17·4	30·85
5% . .	11·7	17·9	31·00
8% . .	12·3	18·6	33·00

Compressive Strength

From the results of compressive strength obtained for all types of specimens it can be seen that lime is responsible for the development of wet compressive strength. For cylindrical specimens the 28 day strength is very low (8 to 12.6 kg/cm²) for the soil S—3 which is highly silty. For the soils S—1 and S—2 it is of the order of 16.5 to 36.5 kg/cm². These soils contain sand around 50% or more and were studied further for making full size bricks. A substantial increase in the compressive strength was obtained as a result of subjecting the 28 days cured specimens to alterante wetting and drying for the durability testing. This might be due to the reason that keeping the specimen at 70°C for long periods has resulated in the acceleration of lime silica as well as lime carbonation reactions. This point is of special interest regarding the use of lime stabilized soil for building walls in tropical climates with high atmospheric temperatures in Summer and rainy season both spanning over a large period of the year.

The results further point out to the marked increase in the compressive strength of soil compacted under applied pressure. Bricks of wet compressive strength between 20—45 kg/cm² can easily be made under an approximate pressure of 80 kg/cm² (app ½ ton/sq. in) as against those of 13 to 26 kg/cm² on hand operated press. Application of pressure besides increasing the dry unit of the soil brings its particles closer to each other. The latter factor is of special importance in the lime-soil system since besides flocculating effect of lime on soil minerals it is to a significant extent the result of lime soil reactions. The closer the particles of the reacting components the faster the chemical reactions. These blocks or bricks prepared under pressure possess adequate strength for use in the construction of walls of single or double storey houses. Rammed soil mix which develops an ultimate strength of this order can be used in the foundation in place of lean concrete and also in making sub floors in lieu of lime concrete presently in vogue. To make such bricks a suitable brick press such as the one used for making refractory bricks can be used but there is a need of a special press with a higher output to be designed for this purpose alone which can exert a minimum applied pressure between 80—160 kg/cm² ½ ton to 1 ton/sq. in). Dry strength of full size bricks has also been determined mainly from the view point of their suitable suitability for handling transhipment etc.

Compressive strength value obtained for brick made by means of hand operated brick press are given in Table II. Compressive strength of water saturated brick ranges between 13 to 26 kg/cm² which can be considered adequate for the purpose of construction of walls of single storey houses and huts in the rural areas. A survey of literature on the minimum compressive strength requirements for stabilized bricks reveals that the following values have been recommended.

(i) South Africa[6] .	14.2 kg/cm²	min. 28 days wet strength
(ii) India[5] .	18 kg/cm²	28 days wet strength
(iii) Ghana[7]	14 kg/cm²	Do.
	28·5 kg/cm²	min 28 days dry strength

The above recommendations have been made for soil-cement blocks and are based on the experience gained by their actual use. Whether the same strength specifications should be applicable to lime, stabilized blocks also, if desired, shall have to be considered in the light of the fact that the development of 28 day strength in soil-lime is usually lower than the soil-cement although in the former the ultimate strength may exceed that of the latter during the course of time. Fitzmaurice[8] has further suggested that the 28 day strength requirements of soil-cement for construction of houses should be reduced to 7.1 kg/cm² in case of soils containing gravel to the extent of 70 per cent. This indicates that while fixing specifications of strength for stabilized soil also there is an obvious tendency to give due considerations to the material behaviours and economy under almost similar situation of use. The authors, also feel that in case of bricks made on a hand operated press the strength specifications can be brought down to a reasonable extent considering

economy and that the strength obtainable in the field is bound to be lower than what can be achieved in the laboratory. The bricks can be made at the site of use, since the machine is easily transportable.

Shrinkage and Moisture Movement

Drying shrinkage and moisture movement subseqeunt to drying are the factors which may be the cause of cracks, rain penetration and separation of the applied plaster on the walls if they are excessive. It has been suggested that the limits of shrinkage in the stabilized soil blocks should also be the same as prescribed for concrete blocks[9] between 0.05 and 0.02 per cent. It will be seen from the values of shrinkage observed on the brick specimens made on a hand operated press that they are much lower in the case of the soils studied. Moisture movement values are still lower and are not expected to cause any defect mentioned above.

Water Absorption

Water absorption of compacted soil specimens has been shown in Table I. The values are within limits as required in Indian Standards Specifications[5]. Water absorption figures obtained for bricks of hand operated press range between 17 and 19 per cent. These are not shown in the tables.

Natural Weathering

Neither of the brick panels erected for natural weathering has shown any deterioration up to a period of three years. Panel marked A is in an excellent condition and has improved in apperance. Panel marked D is also in good condition as compared to what it was in the beginning. In this case while there is no change in the condition of the brick a slight erosion of the jointing mortar was observed in the early stages.

CONCLUSIONS

Although the investigations carried out are of a limited magnitude, the authors have been able to draw the following conclusions regarding the potentialities of lime stabilized soil as a construction material. Obviously the conclusoins are valid only for the types of soil studied i.e. alluvial soils.

(i) Alluvial soils containing sand between 50 and 78 per cent have been found suitable for stabilization with lime for the purpose of making lime-soil bricks. Soil which contains about 17.8 per cent clay and about 53 per cent silt i.e. which is highly silty has not been found suitable for stabilization with lime.

(ii) Lime brings about the development of the wet strength in the compacted soil continuously up to the quantities used i.e. 8% by weight of soil. The effect is quite perceptible in normal curing conditions up to 28 days but becomes more pronounced under alternate wetting and drying conditions prescribed for durability testing. Application of high pressure considerably improves the strength and stability of the soil. Soil blocks possess quite low shrinkage and moisture movement characteristics.

(iii) Soil stabilized with lime can be used as a building material for the construction of walls in the form of bricks and blocks. The strength requirements of such units may be the same as for soil-cement in case of their use in load bearing walls but the specifications may be brought down for non load bearing applications such as filler blocks or for single storey houses or huts where the roof load does not rest entirely on the wall. To make such units a hand operated brick press can be employed at the site.

(iv) Compacted soil-lime mix can be used in foundations and under the floors in place of lean or lime concrete.

(v) Soil lime bricks or blocks can be a potentially suitable material for the construction of walls in rural areas and the cost of houses can be considerably reduced if the making of walling units and other jobs are carried out on self help basis and small lime kilns, catering to local needs, are set up on regional basis.

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TABLE 1

Physical Properties of Cylindrical Specimens (5 cm × 10 cm) of Lime-Stabilised Soil cured for 28 days under 90% humidity

Soil Type	Lime in the mix (% by wt)	Wet Comp. Strength 14 days	28 days	Kg/cm² After weatheing tests as per IS:2185-1968	Maximum dry Density gm/cc	Water Absorption (% by wt.)	Shrinkage %	Moisture Movement %
	3	21.0	25.5	28.5	1.93	11.3	0.002	Negligible
S—1	5	24.1	30.6	35.5	1.91	11.7	0.002	,,
	8	30.5	36.5	48.8	1.88	12.1	..	,,
	3	16.5	18.2	20.1	1.88	12.0	0.05	0.008
S—2	5	19.2	25.0	32.7	1.85	12.5	0.04	00.05
	8	26.5	29.5	42.5	1.83	12.9	0.04	00.05
	3	5.6	8.0	..	1.34	16.4	..	..
S—3	5	7.4	9.0	..	1.33	16.6	..	..
	8	10·6	12·6	..	1·29	18·6	..	..

TABLE II

Compressive Strength (Wet) data of Lime Stabilized Soil Bricks, Kg/cm²

Press	Lime in the soil mix, % by wt.	Soil S-1				S-2			
		14 days		28 days		14 days		28 days	
		Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Hand Operated Press	3	14·1	28·0	17·3	30·4	13·2	35·0	13·4	37·0
	5	16·8	30·2	20·6	35·0	14·9	37·2	18·5	37·5
	8	18·2	36·6	22·4	38·3	17·8	38·5	23·0	39·9
Power Press	3	22·0	48·1	26·8	52·6	18·4	48·0	20·8	45·2
	5	25·5	57·4	30·0	58·8	20·0	57·0	24·0	58·1
	8	35·2	60·0	38·5	62·5	27·7	60·5	32·1	64·6

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