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STUDY ON ALTERNATIVE MATERIALS USED FOR INTERLOCKING COMPRESSED STABILIZED EARTH BLOCKS(ICSEB)

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Abstract*— The popularity and dependency of the majority of population on masonry alone demands further study on this field. We proposed a study on the interlocking blocks which are being more popular these days, with different locally available material like fly ash, limestone dust, saw dust ash etc. for stabilization and higher compressive strength. A total of 40 samples of ICSEB (Interlocking Compressed Stabilized Earth Block) were produced for the research purpose consisting with varied proportions of different materials. The samples were batched, prepared and compacted as per the proportions decided from thorough study, literature review and field experience. The best sample obtained on the basis of cost for 1 cubic meter wall as well as sample crossing the nominal compressive strength was found to be the block with 15% saw dust ash with amount 22% less than the red clay brick and the cheapest brick per unit among all was found to be sample containing 30% sawdust costing NPR 24.6 but it had lesser strength than nominal compressive strength as required by Nepal Building Code (NBC-202). The unit block prepared with lime and cement at equal proportion of 7.5% showed highest compressive strength among all the samples.

***Keywords*— ICSEB, Earth Block, Fly Ash, Cement Stabilization, Lime, Saw dust stabilization**

I. INTRODUCTION

If the blocks are stabilized with a chemical binder such as Portland cement they are called compressed stabilized earth block (CSEB) or stabilized earth block (SEB).

Ideal Earth Bricks consists of Soil, Sand and 10% Cement. The mixture is compressed in a machine which results in a compacted brick with high density. The bricks are then stacked and cured for 28 days. The soil compresses, which adds to the high density and strength. The precise composition of the soil should be around 50% sand, 20% clay, 15% gravel and 15% silt. Normally we don't get the exact proportion of soil. So, first the soil is tested and then sand and gravel is added until this ratio is obtained. This way we can ensure the same bricks strength in any structures. [1]

A. Cement stabilization:

Cement is considered a good stabilizer for granular soils but unsatisfactory for clays. Generally, cement can be used with any soil type, but with clays it is uneconomical because of requirement of higher cement. The range of cement content needed for good stabilization is between 3% and 18% by weight according to soil type. [2]

B. Lime stabilization:

The pozzolanic reaction is believed to be the most important and it occurs between lime and certain clay minerals to form a variety of cementitious compounds which binds the soil particles together.

Lime can also reduce the degree, to which the clay absorbs water, and so can make the soil less sensitive to changes in moisture content and improve its workability. [2]

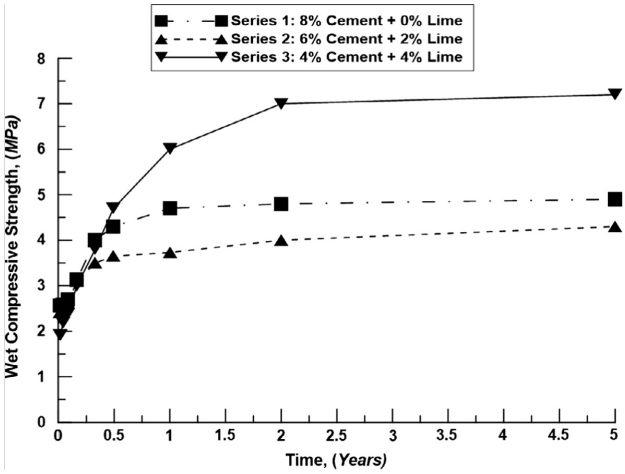

Fig. 1. Wet compressive strength variation with lime content and time [3]

C. Energy consumption and carbon emission:

TABLE I. TABLE FOR EMISSION SAVING & ENERGY SAVING FOR CSEB

Pollution emission (Kg of CO_2/m^2)	**7.9 times less than country fired bricks**
Energy consumption (MJ)	15.1 times less than country fired bricks
Ecological comparison of building materials	

[4]

The red clay bricks, usual choice for masonry construction has been polluting the environment through its higher carbon emission. The ICSEB blocks though are more environmentally friendly which also is depicted in the above table which is favorable in terms of energy consumption and pollution emission as well.

II. METHODOLOGY

A. Specimen preparation:

The major factors governing the selection of materials included the cost-effectiveness of these materials, strength expected from their use, local availability and their environmental impacts.

The range of cement content needed for good stabilization is between 3% and 18% by weight according to soil type [2]. So, the stabilizers content was maintained at 12.5%.

1) Sample proportions:

Sample A was the blocks available at the market with 12.5% cement. Sample L1, L2 and L3 were samples where lime was added in different proportions of 5%,7.7% and 9.4%. Sample F1 and F2 were samples consisting fly ash at 15% and 30% respectively. Sample S1 and S2 were the samples containing saw dust ash at 15% and 29.2% with no any soil content.

Sample size : 30 cm*15 cm*10 cm (l*b*h)

TABLE II. SAMPLES PREPARED FOR EXPERIMENTS

	A	Normal ICSEB
Lime Dust Containing ICSEB	L1	5% Lime Content
	L2	7.7% Lime Content
	L3	9.4% Lime Content
Fly Ash Containing ICSEB	F1	15% Fly Ash
	F2	30% Fly Ash
Saw Dust Containing ICSEB	S1	15% Saw dust
	S2	29.2% Saw dust

2) Sieving:

In the field, we used single sieves nailed to a supporting wooden frame. The sieving of primary materials, soil and stone dust, was carried out on 10 mm sieves whereas sand was sieved on 6mm wire mesh. Likewise, the sieving of additional materials, saw dust ash, was carried out on 6 mm sieves due to presence of excessive foreign materials in spite of its very fine nature.

3) Proportioning:

The proportions by weight of primary materials i.e., soil, sand, stone dust and cement were altered for each type of ICSEB and different materials were added accordingly.

4) Batching:

Batching is the process of measuring the amount of brick ingredients, either in weight or volume in the required proportion for introduction of the materials into the mix. Proper and accurate batching process were carried out in production of ICSEB's in order to ensure uniformity in proportion.

5) Mixing:

In the field, Dry materials were mixed first until they were of uniform color, then water was sprinkled little at a time over the top of the mix from a watering can with a rose spray on the nozzle and mixing was continued until a homogeneous mix was obtained. The mixing was performed in accordance to the usual practice in block industries.

Fig. 2. Mixing of the materials in the field

6) Placement and compaction:

This was carried out in field by using standard techniques suggested by our field supervisors. The readied mix was placed into the machine and compaction was carried out by the hydraulic machine.

Fig. 3. Molding of the bricks after compaction

7) Molding:

The compaction process ensured smooth finishes on all sides of the blocks. ICSEB blocks were made 30cm x 15cm x 10cm size from a manual compaction machine. As the blocks were not fully set, they were weighed without disturbance and placed on wooden planks in shade for 24 hrs before curing.

8) Curing:

As the blocks were cement and lime stabilized, it needs sufficient curing as shown in the figure to achieve higher final compressive strength. In field, the block stacks were covered by using plastic bags to prevent moisture from escaping. Wet jute bags were provided on top of the stacks.

Curing process required application of required volume of cold water from the top of stacks two times a day and was carried up till 28 days.

9) Compressive strength test:

The compressive strength tests for block samples were carried out in a conventional manual hydraulic compressive strength testing machine.

The samples A, L1, L2, L3, S1 and S2 were tested at 14 and 28 days. 3 samples for each brick were tested. Sample F was tested only at 28 days due to presence of less number fly ash containing brick samples.

10) Cost calculation:

The cost per bricks were calculated on the basis of machine catalogue which showed the number of labors required for production of bricks per day. The labor cost was included accordingly with 15% of profit for the manufacturer and the materials density was assumed for the calculation of the cost of materials because the rate available according to district rate was in terms of volume. The air voids are not considered and for the one cubic meter wall, wastage was assumed 5% for bricks with 10% mortar thickness and 30% dry volume of mortar. Water to cement ratio was taken as 0.6.

III. Results, Analysis and Discussion:

A. Variation of compressive strength with time:

The above graph shows the average compressive strength of all the types of CSEB's obtained after 14 and 28 days. L1 type showed the best results on tests performed at 14 days i.e., 2.311 MPa. Likewise, S1 and A types also showed relatively better initial strengths i.e., 2.152 and 2.126 respectively. L2 type showed moderate strength of 1. 97 MPa whereas S2 and L3 types were found to possess lesser 14 days compressive strength and L3 being the weakest with an average compressive strength of just 1.659 MPa.

As shown in the graph, the nominal compressive strength after 28 days is 3.5 MPa([5]. Most of the produced types of CSEB's were able to obtain higher strength values than the required 3.5 N/mm^2 if F2 and S2 types were excluded. The highest average 28 days strength obtained among all the tested types was found to be 4.296 MPa of L2 type CSEB. The combination of lime and cement as binding materials was found to more effective for long term strength as all such types (L1, L2 & L3) surpassed the strength of type A brick containing only cement as a binding material. The decrease in fly ash to a total of 15% by weight showed an increase in the strength to 3.75 MPa.

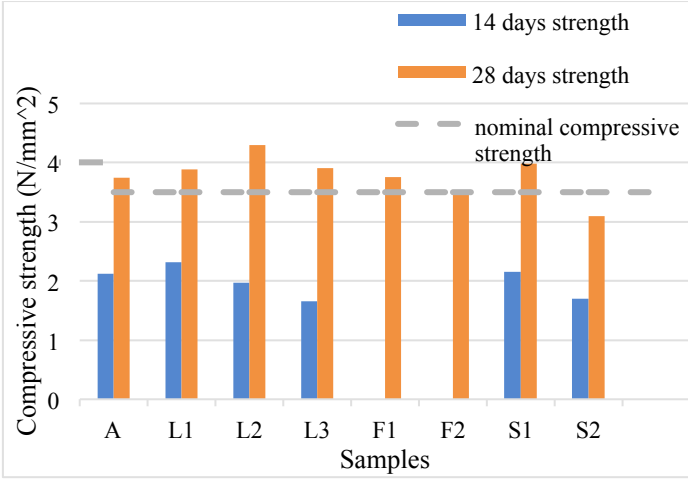

Fig. 4. Variation of compressive strength with days.

This implies the successful use of the waste materials in CSEB's blocks and also signifies the requirement of proper proportioning for achieving proper strengths of the blocks. Overall, the obtained values showed that the calculated use of alternative materials such as fly ash and saw dust ash in the given proportions didn't jeopardize the quality in strength to an unacceptable limit, keeping in mind the need of an economic result.

B. Cost analysis:

TABLE III. Unit block cost

SN	Bricks	material cost(Rs.)	Labor cost (per block)	Profit (15%)	Total cost per block
1	A	24	6.7	4.6	35.3
2	L1	25.6	6.7	4.8	37.1
3	L2	27.1	6.7	5.1	38.9
4	L3	28.6	6.7	5.3	40.6
5	F1	30.4	6.7	5.6	42.7
6	F2	32.4	6.7	5.9	45.0
7	S1	22	6.7	4.3	33.0
8	S2	14.7	6.7	3.2	24.6

The table above shows the compressive strength of bricks and their unit cost. The compressive strength of L2 was found to be the greatest among all but not much cost efficient. From the bar chart just according to unit cost and strength, red clay bricks were found to be the best as shown. After that L2 had higher strength but due to more cost per brick than S1, S1 would be better since the strength is above the nominal strength as specified by Nepal government but we can't just consider unit cost since the size of ICSEB and the red clay bricks differ to one another. So, the rate analysis of brickwork was carried out per cubic meter and thus the cost per cubic meter wall was compared as shown in next bar chart.

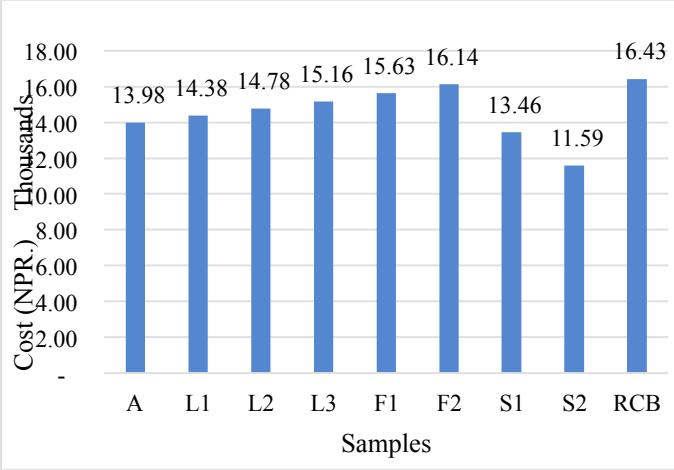

Fig. 5. Cost for one cubic meter brickwork

The bar chart above shows the cost of brickwork for 1 m^3 wall. The standards were maintained and calculated for both the ICSEB and red clay bricks. The cost per unit ICSEB was found to be expensive than the red clay bricks but due to their size variation, the rate for 1 cubic meter brickwork was found less than that of red clay bricks. The price was found to be varied by around NPR 2500 when compared to the sample A, which is the sample that is made in the factory, with red clay brick unit m^3 work. But the sample S1 varied with the red clay bricks by nearly NPR. 3000 which is more beneficial than sample A.

Thus, just by comparing the cost sample S1 was found to be the cost efficient among A and red clay bricks and also since S1 had unit strength above the nominal, S1 is considered the better considering both unit strength as well as cost per cubic meter wall.

CONCLUSIONS

Thus, for the above results and discussions, it is clear that the unit cost of red clay brick is much lesser than the ICSEB. It also has got the higher strength than all the samples of ICSEB. Considering only unit cost and strength the ICSEB cannot replace the red clay bricks but from the rate analysis of brickwork for 1 cubic meter, ICSEB normally produced sample and sample containing 15% saw dust ash was found to be much lesser than the brickwork for red clay bricks and the two sampes had their unit compressive strength above nominal strength which is 3.5 N/mm^2. The commonly produced ICSEB's in the factories all over Nepal is sample A showed unit strength lesser than sample with 15% saw dust. Compared to the unit cost of normally produced sample, sample with 15% saw dust ash sample showed less cost per unit sample for production. Thus, sample with 15% saw dust ash was found to be a better option suited in all the aspects among the ICSEB. Likewise, in terms of strength, the best produced sample was L2 (Lime & cement stabilized blocks with each at equal amount) with a compressive strength of 4.296 MPa. Sample with Sawdust of 29.2% was found to be the most economic among all the compared samples but possessed relatively lower strength of 3.093 MPa. Some other conclusions can be stated as follows:

- Lime could be used at equal proportion by weight with cement as binding material in places of availability, which was found to give better strength.
- The increment of fly ash as well as saw dust ash caused decrement in the compressive strength of the bricks.
- The compressive strength decreased with increased water absorption.
- Samples containing lime showed better long-term strength than samples with only cement as a binding material.

RECOMMENDATIONS

Some recommendations for further study can be listed as follows:

- Study of different types of ash can be done such as rice husk ash or different classes of the fly ash can be used for the bricks.
- There is a need to study of flyash lime bricks further without use of soil.
- The ICSEB can be studied and compared for soils having different properties.
- The comparison between use of OPC and PPC cement can be done.
- Comparison can be done by the use of different machines as well which has various forces.
- Need of study of lime powder as binding material due to long term strength and availability.

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