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Studies on Cement Stabilsed Mud Blocks for Sludge Disposal from MgO, $CaCl_2$, CaO and HCl Based Defluoridation Filters in Rural Rajasthan

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Abstract: Sludge obtained from defluoridation filters based on MgO, $CaCl_2$, CaO and HCl have been used to make cement stabilized mud blocks using local soil with high sand content. Stabilised mud blocks with 9 % cement and 10, 12, 14, 16% sludge and different water contents have been made using a Balaram Mud Making Machine. On determining their 28th day compressive strength, it was observed that as the percentage of sludge was increased, the blocks had lower compressive strength Fluoride leaching tests were conducted using DM water and TCLP extractant 2. It was found that in both cases fluoride leaching was below the permissible limit of fluoride in drinking water (1.5 ppm).
Keywords: defluoridation filter, stabilized mud blocks, compressive strength, TCLP.

1 Introduction

Stabilized Mud Blocks (SMB) is a good alternative source of building material. These can be used in place of ordinary burnt bricks made of clay[2]. Compaction and stabilization of mud blocks using cement improves the density and the strength of mud blocks[3]. Various waste materials like flyash[4], cigarette butts[5], cement kiln dust[6], plastic waste[7], copper mine tailings[8,9] and coconut fibre[10] etc. have been incorporated into mud cement blocks as a method for their safe disposal.

Recently a low cost defluoridation filter using MgO, $CaCl_2$, CaO and $NaHSO_4$ has been developed at IISc Bangalore in India[11,12,13]. As a part of Water Technology Initiative of the Department of Science and Technology, New Delhi, field trials of the filter have been carried out in the fluorosis affected desert state of Rajasthan in India. Considering the different ground water characteristics of Rajasthan and Bangalore, the fluoride filter has been suitably modified by us[14,15,16] by using dil. HCl instead of $NaHSO_4$.

The sludge from the filters developed at IISc have been encapsulated in cement stabilised soil blocks using locally sourced (IISc Bangalore) red soil and river sand[17]. The blocks had adequate strength and low fluoride leaching. The area in which the present field trials of the filter are being carried out is arid, semi desert like with sandy soil. Keeping the above in view, and as a project requirement, an attempt has been made to safely dispose the sludge from these filters by incorporating them into cement stabilized mud blocks using locally sourced soil with high sand content and in this chapter we report the findings of such a study.

2. Experimental

2.1 Conversion of Sludge into Stabilized Mud Blocks

2.1.1 Drying of Sludge

The sludge from both lab trials and field trials of the defluoridation filter were combined together in 50 lit. plastic containers. The sludge was placed in sunlight, in plastic tubs for drying till it was free from moisture (constant weight).

2.2.2 Testing of Soil for Making Mud Blocks

Soil used for making blocks were brought from local brick kilns and 2 kg soil sample were sent for soil testing to Geo Tech Technical Associates, Varanasi. The maximum dry density, optimum water content (standard proctors test) for the soil samples, particle size analysis, liquid limit, plastic limit, plasticity index have been determined and are reported in table 1.

2.2.3. Determination of Optimum Water Content for 100% Soil Blocks

5000 gm soil was mixed with different percentages of water and made into mud blocks using a Balaram Mud Block Making Machine (Development Alternatives, New Delhi). The blocks were dried in shade for seven days and their compressive strength measured, using a Universal Testing Machine (Techequip, U.K). The experiments were done in duplicate. The compressive strength of various blocks are given in fig. 1

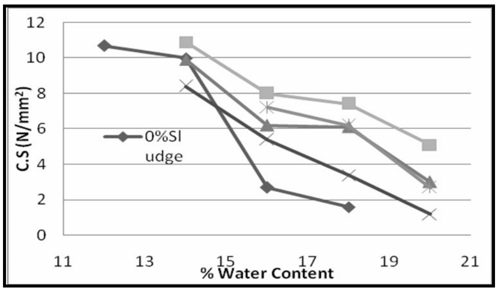

Fig.1 Variation of Compressive Strength for Compressed Mud Blocks Containing 9% Cement + 0-16% Sludge + 12-20% Water

2.3.4. Determination of Optimum Water Content for Soil and 9% Cement Blocks

4600 gm soil and 414 gm cement were mixed with different percentages of water and made into mud blocks using Balaram Mud Block Making Machine (water content calculated based on the weight of soil + cement). The blocks were dried in shade for 28 days and their compressive strength measured using a Universal Testing Machine. The experiments were done in duplicate. The compressive strength of various blocks are given in fig. 2

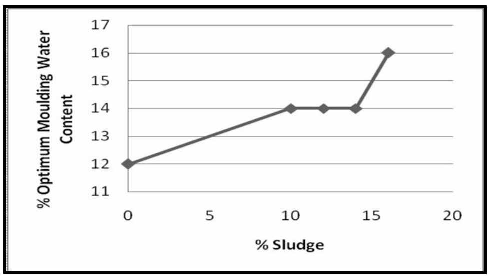

Fig. 2 Variation of Optimum Moulding Water Content (OMWC) for Compressed Mud Blocks Containing 9% Cement + 0-16% Sludge

2.3.5. Determination of Optimum Water Content for Soil, 9% Cement and 10, 12, 14, 16% Sludge Blocks

Different weights of soil, cement and sludge were mixed with different percentages of water and made into mud blocks using Balaram Mud Block Making Machine (water content was calculated on the base of soil + 9% cement + 10, 12, 14, 16% sludge). The blocks were dried in shade after covering them with wet burlap for

28 days and their compressive strength measured using a Universal Testing Machine. The experiments were done in duplicate. The compressive strength of various blocks is given in fig. 1

2.2 Fluoride Leaching Tests

Leaching with Demineralised Water (DM) (< 1 μmhos/cm)

2.2.1 Leaching of Fluoride from Sludge, 100% Soil Blocks, Mud + 9%Cement Blocks, Mud+9%Cement+ 10, 12, 14, 16% Sludge Containing Blocks

The dried sludge/soil blocks/soil-cement blocks/soil-cement-sludge blocks were crushed and passed through a 4.75 mm sieve. The powder was mixed with DM water (1:20) and shaken on a rotary shaker for 18 hrs. The mixture was filtered and the F^- concentration was determined. The experiments were done in duplicate. The results are given in table 2.

2.2.2. Leaching of Fluoride from Sludge, 100% Soil Blocks, Soil + 9% Cement Blocks, Soil + 9% Cement + 10, 12, 14, 16% Sludge Containing Blocks using TCLP Extractant 1 or 2

The dried sludge/soil blocks/soil-cement blocks/soil-cement-sludge blocks were crushed and passed through a 4.75 mm sieve. The powder was mixed with TCLP extarctants 1 or 2 (1:20) (the extractants 1 and 2 have been prepared by standard procedures) and shaken on a rotary shaker for 18 hrs. The mixture was filtered and the F^- concentration was determined. The experiments were done in duplicate. The results are given in table 2.

Table 2 Results of Leaching Tests for Fluoride

Materials	Fluoride conc. in DM Water extract (ppm)		Fluoride conc. in TCLP extract 2 (ppm)	
	Sample1	Sample 2	Sample1	Sample 2
100% Sludge	0.789	0.784	0.750	0.680
100% Soil blocks	0.289	0.267	0.268	0.322
Soil + 9% cement blocks	0.298	0.345	0.285	0.276
Soil + 9% cement + 10% sludge blocks	0.489	0.465	0.334	0.288
Soil + 9% cement + 12% sludge blocks	0.556	0.483	0.368	0.397
Soil + 9% cement + 14% sludge blocks	0.509	0.499	0.497	0.483
Soil + 9% cement + 16% sludge blocks	0.703	0.646	0.591	0.596

Fig. 3 Photograph of the installed Balaram Mud Block Machine

Fig. 4 Photo of dried sludge from the filter

Fig. 5 Photo of the fabricated sludge mud blocks

Photographs of the Balaram Mud Block Machine, dried sludge and fabricated sludge mud blocks are shown in fig. 3, 4 and 5.

3 Results and Discussion

The results of the soil testing are shown in table 1. The soil has a high sand content (total sand 90%) and low silt content. The soil is non plastic in nature.

Table 1

S. No.	Test	Result
1.	Gradation	
a.	Gravel (%)	0
b.	Sand (%)	
	Fine (%)	88
	Medium (%)	2
	Coarse (%)	0
c.	Slit + Clay (%)	10
2.	Liquid Limit (%)	Non Plastic
3.	Plastic Limit (%)	
4.	Plasticity Index (%)	
5.	Maximum Dry Density (MDD)gm/cc	1.76
6.	Optimum Water Content (OMC)	14.5

The manufacturers of the TARA Mud Block Machine recommend soils with 40-60% sand, 20% clay, 20% silt and 7-10% of fine gravel for block making. A water content of 10-14% by weight of soil is recommended depending upon the type of soil used. The OMWC of the blocks are shown in table. 1.

From the above studies it is clear that addition of 9% cement to the 100% soil blocks increases the compressive strength of the blocks from 2.4 to 10.7 N/mm^2. On adding 10% sludge to the 9% cement-soil block does not alter its strength significantly (10.9 N/mm^2). However, on increasing percentage of sludge from 10-16%, lowers the strength of the mud blocks (from 10.9 to 7.2 N/mm^2).

Fluoride leaching tests were done to determine the environmental safety of theses blocks. Notice that the leaching of fluoride using DM extract and TCLP extracts showed very less leaching of fluoride from the blocks, while moderate leaching of fluoride from the dried sludge was observed. Also notice that as the percentage of sludge was increased in the blocks, the fluoride concentration in the leachate correspondingly increased. We observed that the leaching of fluoride from sludge blocks using DM water was more than using TCLP extractant. This shows that conversion of sludge into cement stabilized mud blocks is an efficient process of environmentally safe disposal of sludge.

Wet compressive strength of 3-4 MPa is sufficient of construction of load bearing structures[12]. Thus the compressive strengths of 10.9 MPa found these blocks meet these requirements.

The maximum strength of soil, cement, sludge blocks (10.9 N/mm^2) is at the following ratio; 9% cement + 10% sludge (based on soil) + 14% water (based soil + cement + sludge). This slightly more than strength of soil + 9%cement+ 10% sludge blocks made with 14% water as reported Rao et al[12]. However, notice that the local soil used contains 90% sand as compared to 76% sand in the soil used by Rao et al[12].

4 Conclusions

We have effectively demonstrated that the sludge from the MgO, $CaCl_2$, CaO and HCl based defluoridation filter can be converted into cement stabilized mud blocks of adequate strength using local soil. These blocks meet the compressive strength of load bearing structures. Leaching of fluoride from these blocks was also low, indicating that this method of sludge disposal is environmentally friendly.

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