Journal of the University of Chemical Technology and Metallurgy, 41, 4, 2006, 473-478

CHARACTERIZATION AND REUSE OF TEXTILE EFFLUENT TREATMENT PLANT WASTE SLUDGE IN CLAY BRICKS

R. Baskar, K.M. Meera Sheriffa Begum, S.Sundaram*

Department of Chemical Engineering,
National Institute of Technology,
Tiruchirappalli - 620 015, Tamilnadu, India
E-mail: ssundar@nitt.edu

Received 02 February 2006
Accepted 12 November 2006

ABSTRACT

The recent trend in waste management is to reuse the industrial waste in usable products. In this context, feasibility of using sludge generated in wastewater treatment plants of textile industry as a partial replacement for clay in the conventional brick manufacturing process is examined. Physico-chemical and thermogravimetric (TG) properties of the sludge have been studied. The effect of the sludge composition (3-30 % w/w), the firing temperature (200-800°C) and the firing time (2-8 h) on the quality of the bricks formed is examined. All the brick samples satisfied the requirements of the Bureau of Indian Standard (BIS) norms in terms of shrinkage and weight loss characteristics. However, bricks with more than 9 % sludge did not to satisfy the prescribed norms for compressive strength at the maximum range of temperature studied. Thus textile sludge up to 9 % w/w can be effectively added to make brick material and such a study will open up a new area of research in disposal and reuse of this waste sludge. Detailed leachability studies and identifying means to increase the sludge addition beyond the maximum condition is being further pursued.

Keywords: textile waste, sludge bricks, common effluent treatment plant, thermogravimetric analysis.

INTRODUCTION

The textile industry occupies an important place in the economy of the India [1] and other developing countries. Textile processing consumes enormous quantity of water and chemicals for various operations like washing, dyeing, etc. [2]. The low efficiency of chemical operations and spillage of chemicals cause a significant pollution hazard and make the treatment of discharged wastewater a complex problem. Most of the wastewater treatment plants presently adopt methods of chemical precipitation and subsequent clarification. Groups of textile industries are joining together to form common effluent treatment plants (CETP) in order to economize the process.

In CETPs, raw wash effluents from various textile units are collected, homogenized and then pumped to the flash mixer where flocculants and lime solution are added. The flocculant addition leads to particle destabilization and is very effective in removing dyes. Since the addition of flocculants decreases alkalinity, lime is dosed to prevent any abnormal decrease in pH value, which may affect the flocculation. The effluent from the flash mixer flows to a clariflocculator where polyelectrolyte is dosed which assists in particle bridging and compaction of the sludge. The over flow from the clariflocculator is transferred through a sand filter to a static mixer where sodium hypochlorite is added to remove any remaining organic and residual colour. The sludge thus formed is first transferred to the thickener for concentration of solids and then dewatered in a centrifuge. The dewatered sludge from the centrifuge is allowed to stabilize and dried in sludge drying beds.

The sludge which is an inevitable solid waste from these wastewater treatment processes is categorized under toxic substances by statutory authorities. Presently huge quantities of sludge are dumped in protected areas in the treatment plant premises and await a suitable disposal method. As the amount of sludge produced by wastewater treatment plants increases effective reuse and safe disposal of sludge becomes more important. The conventional disposal methods like landfilling and incineration may not be suitable because the leachate from the landfilling sites and the residues from the incinerators induce secondary pollution. Moreover such disposal options are not economically viable. The sludge as such cannot be applied to fertile lands because of its chemical contents.

Many scholars in different disciplines have studied how to convert waste sludges from domestic and industrial operations into useful products, such as retrieving the organic components in sludge to improve farm land, palletized aggregate for concrete [3,4], replacing cement in concrete, production of ceramic bricks and tiles [5], mixing sludge with clay to produce building bricks [6-11]. Previous references [12-13] also reported the utilization of textile industry sludge in vermistabilisation.

The use of sludge as construction and building material not only converts waste into useful products but also eliminates disposal problems. Natural resources like clay are also conserved. Benefits of using sludge or sludge ash as an additive to brick include immobilizing heavy metals in the fired matrix, oxidizing organic matter and destroying any pathogens during the firing process and reducing the frost damage.

In this study a systematic investigation on the partial replacement of clay by textile industry CETP sludge in the manufacture of bricks is carried out. In order to obtain suitable manufacturing conditions, the proportion of sludge in the brick, the firing duration and the firing temperature that might affect the qualities of bricks were investigated. From an economic point of view, the sludge amended bricks would cost less in its manufacture since it would take advantage of waste by-products.

EXPERIMENTAL

Sludge collection and preparation

The dewatered and open air dried sludge samples were obtained from textile industry CETP in Tamilnadu state, India. The samples of the sludge were dried at a temperature of 105°C until the net weight was constant. The dried samples were then ground in a ball mill for 30 minutes to reduce the size of large and uneven particles and then directly used as a clay substitute. Clay required for experiment was obtained from a local brick manufacturing plant.

Raw Material Analysis

Homogenized sludge samples were used on dry basis for chemical analysis. All chemicals used were analytical reagent (AR) grade. The samples were analyzed in triplicate and the results were averaged. The pH was determined using a double distilled water suspension of each mixture in the ratio of 1:10 (w/v) that had been agitated mechanically for 30 minutes and filtered through Watman No 1 filter paper. The average particle size is determined by cumulative analysis using a sieve shaker with Taylor's Standard Screens (TSS). Heavy metal constituents were analyzed using Thermosolar 2ASS–Spectra Atomic Absorption Spectrometer (AAS). Thermogravimetric (TG) runs for both sludge and clay were carried out in a Perkin Elmer TGA7 analyser. Platinum crucibles were used in order to get the best possible heat transfer between thermocouples and crucibles to minimize any thermal lag. Dried samples around 10 mg with an average particle size 0.2 mm were used, and the reproducibility of the runs was tested. The assays were performed in a static atmosphere of air, using a heating rate of 50°C/min from the ambient atmosphere to 1235°C.

Formation of brick specimen

Textile CETP sludge is added with a clay up to 30 % by weight in increments of 3 % and mixed well to form a homogenous mixture. Pure clay was used as a standard for comparison. The sample is made pasty with required amount of water based on optimum moisture content. The mixture is degassed to remove the trapped air to avoid the cracking in the firing process. The mixtures were then moulded into 70x70x70 mm cubes in series of batches. After forming, the specimen were dried in open atmosphere for 24 hours and then in an oven for 6 hours at 110°C. The dried samples were then fired at 200, 400, 600, and 800°C in a muffle furnace for different firing times (2, 4, 6, 8 hrs).

Testing of brick specimen

The brick specimens were characterized with respect to compressive strength, water absorption, percentage shrinkage and percentage weight loss. The compressive strength and water absorption were determined as per IS 3495 (Part 1 to 2): 1992 standards [14]. A compression testing machine with 110 cm ram diameter is used to test the compressive strength of the brick samples.

RESULTS AND DISCUSSION

Physico-chemical characterization of raw materials

The estimated physico-chemical properties of the waste sludge dried at 105°C is given in Table 1. The material is brown in colour due to the contribution of significant quantity of iron oxide (9.1 %) present in it. The addition of excess lime during the treatment process makes calcium oxide (28.4 %) as one of major constituent in the sludge and is also responsible for its pH value (10.5). The average particle size determined based on the sieve analysis is 0.285 mm.

Table 1. Physico-chemical properties of textile CETP sludge.

Property	Value
Colour	Brown
Appearance	Agglomerated fine solids
Specific gravity	2.32
Average particle size	0.295 mm
Cadmium	5.6 mg/kg
Copper	119 mg/kg
Chromium	358 mg/kg
Zinc	190 mg/kg
Calcium (as CaO)	28.4 %
Iron (as Fe_2O_3)	9.1 %
Silicon (as SiO_2)	7.1 %
Aluminium (as Al_2O_3)	0.698 %

Thermogravimetric analysis

Studies on thermogravimetric (TG) profiles provide information on the thermal behaviour of the materials and hence on optimum conditions. The TG plot for the sludge (Fig. 1) shows three distinct pattern of weight loss variation with temperature. In the temperature interval of 100-700°C there is a gradual decrease, a steep weight loss in the range of 700-825°C followed

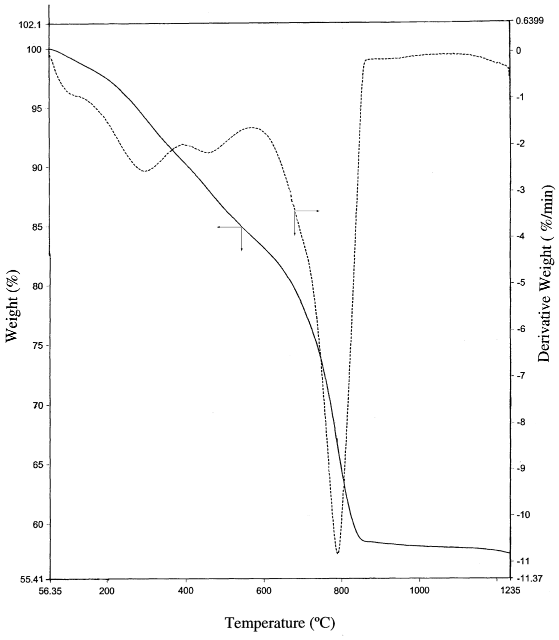

Fig. 1. TG and differential TG plots for textile CETP sludge.

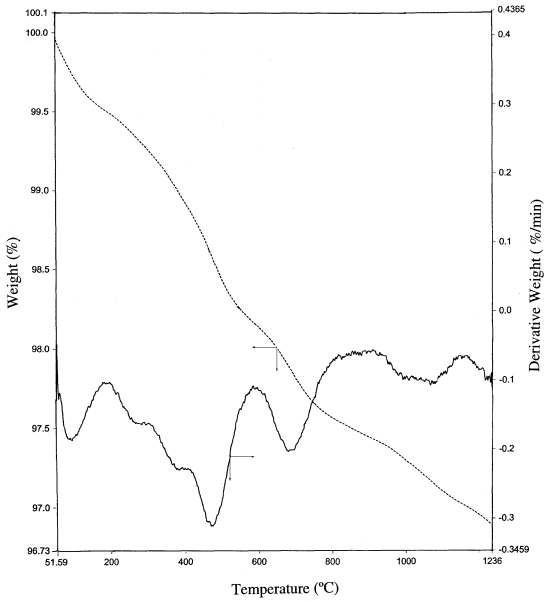

Fig. 2. TG and differential TG plots for clay material.

by negligible variations at higher temperatures. With regard to the derivative weight loss seen in Fig.1 there are three distinct peaks at 295, 380 and 790°C which may be due to the volatile organic matter. The curve then shoots up and forms a plateau at 865°C where the rate of weight loss is negligible. Similar plots for clay material shown in Fig. 2 reveal that clay is thermally more stable with a maximum weight loss of 3.2 %.

Quality of sludge amended brick specimen

The quality of the brick depends on the degree of firing shrinkage, weight loss on ignition, water absorption and compressive strength. Many research reports assess the quality based on the above parameters. A good quality brick must have shrinkage below 8 %, weight loss on ignition below 15 %, water absorption below 20 % and minimum compressive strength of 3.5 N/mm^2 [16].

Effect of sludge addition on compressive strength

The compressive test is the most important test for the engineering quality of a building material. The variation in compressive strength of the brick specimen made from both clay and waste mixture is shown in Fig. 3. It is observed from Fig. 3 that the maximum amount of waste that can be added lies in the range of 6 to 9 % corresponding to a compressive strength between 4.25 to 3.54 N/mm^2 for textile CETP sludge bricks. Therefore bricks were formed with 9 % waste addition and were subjected to different temperature and duration of firing in order to establish the effect of these parameters on the quality of bricks.

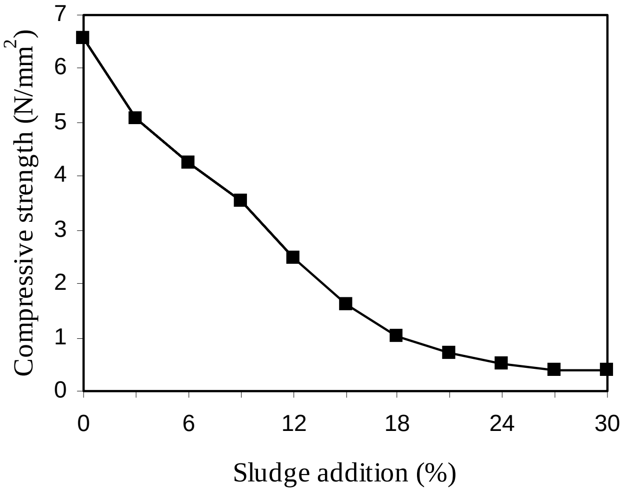

Fig. 3. Effect of sludge addition on compressive strength of bricks (fired at 800°C for 8 hours).

Table 2. Effect of sludge addition on weight loss and shrinkage of the brick specimens at a firing temperature of 800°C.

% Sludge Composition	% Weight Loss	% Shrinking
0	3.41	<0.5
3	4.59	<0.5
6	5.03	<0.5
9	5.38	0.67
12	5.93	0.74
15	6.61	1.04
18	7.32	1.51
21	7.84	1.91
24	8.46	2.53
27	8.87	2.97
30	9.51	3.4

Table 3. Effect of firing temperature on brick quality parameters (9 % sludge amended brick specimens).

Firing temperature (°C)	Compressive strength (N/mm^2)	Water absorption (%)	Weight loss (%)
25*	0.92	--	0
200	1.64	--	1.26
400	2.07	24.19	3.45
600	3.06	18.82	5.73
800	3.65	15.8	7.54

Table 4. Effect of firing time on brick quality parameters (9% sludge amended brick specimens).

Firing time (h)	Compressive strength (N/mm^2)	Water absorption (%)	Weight loss (%)
0	0.85	---	0
2	1.14	22.94	6.31
4	1.69	19.81	7.02
6	2.5	15.8	7.54
8	3.48	12.61	7.98

It is seen that the strength is not only dependent on the amount of the waste in the brick but also on the firing temperature. Compressive strength of bricks decreases with the increase of the waste mix in the bricks, increases with the increase of the firing temperature and

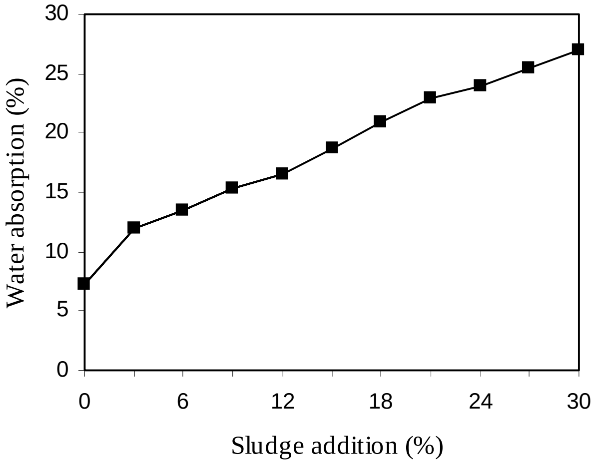

Fig. 4. Effect of sludge addition on % water absorption of bricks (fired at 800ºC for 8 hours).

the firing time. About 70 to 80 % increase in compressive strength is found when firing beyond 400°C (Table 3). The compressive strength increases almost linearly with the time of firing (Table 4).

Effect of sludge addition on water absorption

Water absorption is also one of the key factors affecting the durability of bricks. The lesser the water absorption into the brick, more is the durability and resistance to the natural environment. As shown in Fig. 3, the water absorption is directly proportional to the quantity of sludge added. The increase in the firing temperature results in the decrease in the water absorption and thereby increases weathering resistance as seen in Table 3. The water absorption value decreases with firing time as shown in Table 4.

Effect of sludge addition on firing shrinkage

Table 2 gives the percentage shrinkage and the weight loss in brick samples for different compositions of sludge addition at the firing temperature of 800°C. This temperature has been chosen based on the TG results shown in Fig. 1. The results indicate that up to 9 % addition of sludge there is no appreciable shrinkage in the bricks and beyond that there is an increase in shrinkage. This is because the swelling of clay is much lower than that of sludge; an addition of sludge to the mixture widens the degree of firing shrinkage. All the bricks studied with mix proportion up to 30 % sludge satisfy the norms for bricks shrinkage (below 8 % shrinkage).

Effect of sludge addition on weight loss on ignition

The weight loss on ignition is not only due to the organic content of the mix proportion, but also depends on the inorganic substance being burnt off during the firing process. From Table 2, it is observed that when the sludge composition increases the weight loss is more due to the presence of comparatively more amount of organic and inorganic matter burnt off during firing. Similarly as firing temperature increases, weight loss due to ignition also increases (Table 3). During firing the weight loss is initially high and after about two hours it is negligible (Table 4).

CONCLUSIONS

The usage of waste sludge from textile industry common effluent treatment plant as a clay substitute to produce quality bricks has been studied. All the bricks made with mix proportion (0-30 % waste) were found to satisfy the norms for shrinkage and weight loss properties of quality bricks. The results indicate that the compressive strength is greatly dependent on the amount of waste in the brick and the firing temperature. Compressive strength of bricks decreases with increase of waste mix in the bricks, increases with the increase of firing temperature. It is observed that the maximum amount of sludge that can be added is in the range of 6 to 9 % corresponding to compressive strength values between 4.25 to 3.54 N/mm^2, which satisfies the IS norms.

The amount of water absorption is also directly proportional to quantity of sludge added. Increase in the firing temperature results in decrease in the water absorption thereby increasing the weathering resistance. Compressive strength increases almost linearly with the firing duration. It is concluded from the work that brick – sludge mix with less than 9 % sludge fired at 800°C for more than 8 hours satisfy the criteria for quality bricks.

REFERENCES

1. Textile Ministry, Government of India, Annual report 2004-05, **1,** 2005, 1-17.
2. J.Karthikeyan, S.Venkata Mohan, Advances in industrial pollution control,1st edn. Techno science publications, 1999, 250-251.
3. Chin-Tsou Liaw, J. Haz. Mat., **58**, 1998, 93-102.

4. Joo-Hwa Tay, Sze-Yunn Hong, Kuan-Yeow Show, J.Environ. Eng., **126**, 3, 2000, 279-287.
5. Romualdo R Menezes, J. Eur. Ceramic Soc., **25**, 7, 2005, 1149-1158.
6. J.E. Alleman, Water Sci. Technol., **22**, 12, 1990, 309-317.
7. Pai-Haung Shih, Zong-Zheng Wu, Hung-Lung Chiang, Waste Manag., **24**, 2004,1043-1047.
8. T.Uslu, A.L.Arol, Waste Manag., **24**, 2004, 217-220.
9. Ismail Demir M Serhat Baspinar Mehmet Orhan, Building and Environment, **40**, 2005, 1533-1537.
10. M. Anderson, M. Elliott, C. Hickson, J. Chem. Tech. & Biotech., **77,** 3, 2002, 345-351.
11. M. Anderson, J. Chem. Tech. & Biotech., **77**, 3, 2002, 352-360.
12. V.K. Garg, P. Kaushik, Bioresour. Technol. **96,** 2005, 1063-1071.
13. P. Kaushik, V.K. Garg, Bioresour. Technol. ,**94,** 2004, 203-209 .
14. IS: 3495 (Part 1 to 2), Bureau of Indian standards, 1992.
15. IS: 1077, Bureau of Indian standards, 1992.