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Suitability of Sludge as a Building Material

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Abstract— Different industries produce sludge of different quality and in different quantities. Common method adopted for disposing the sludge is land filling. Landfill disposal of the sludge has drawbacks like high cost of transportation, difficulty in getting suitable sites for land filling, heavy metal contamination of the land, emission of foul gases etc. Thus the disposal of sludge has become a major issue.The objective of this study is to identify the possibilities of using the sludge obtained from effluent treatment plant in Hindustan Latex Limited,Trivandrum as a brick material. The different engineering properties were also studied by conducting tests on brick specimens of various mix proportions prepared.It was seen that when percentage of sludge was increased beyond 60%, water requirement as well as water absorption of the bricks increased by 18%. But at the same time, compressive strength of the brick deccreased by 10.85% . But on addition of cement, flyash and sisal fibres, the compressive strength increased by 30% and thre properties of the bricks improved.Further it can be added that other alternatives like coir fibres,charcoal husk ,lime whose addition shall enhance the properties which can be considered as the scope for future research.

Index Terms— Brick,Cement,Compressive strength,Effluent,Flyash,HLL Lifecare Limited,Moisture,Property,Sisal fibres,Water absorption

1 INTRODUCTION

A large quantity of sludge is generated each year from various industries. The quantity of the sludge produced depends upon the amount of wastewater and the type of treatment adopted for treating the wastewater. Common method adopted for disposing the sludge is land filling. Landfill disposal of the sludge has drawbacks like high cost of transportation, difficulty in getting suitable sites for land filling, heavy metal contamination of the land, emission of foul gases etc. So, disposal of sludge has become a major issue. The use of sludge in construction industry is considered to be the most economic and environmentally sound option.This study focuses on the possibility of using sludge as a brick material[1]. The sludge for this study was collected from HLL Lifecare Limited; Peroorkada,Trivandrum. The main raw material used in this industry is Latex (colloidal suspension of very small polymer particles in water). The bricks were subjected to compressive strength test and water absorption test and thus their suitability for construction purpose was examined[2].

1.1HLL (formerly Hindustan Latex Ltd.)Lifecare Limited

Hindustan Latex Limited or HLL Lifecare Limited is a Government of India undertaking, under the Ministry of Health and Family Welfare, Government of India, which started as a corporate entity in March 1966. Their product ranges from contraceptive aids and healthcare aids to social marketing products.HLL gives emphasis on effective quality control at every manufacturing stage right from the raw material to the final product, during its various production stages.

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1.2 Literature Review

A study was conducted on the use of recycled paper processing residues in making porous brick with reduced thermal conductivity by Mucahit Sutcu et.al.(2009)[3]. In this study mixtures containing brick raw materials and the paper waste were prepared at different proportions (upto 30% by weight). The results obtained showed that the use of paper processing residues decreased the fired density of bricks down to 1.25 g/cc. Compressive strengths of the brick samples obtained in this study were higher than that required for standards.

Another study conducted by Chih-Huang Weng et.al (2003) investigated [4]the influence of sludge proportion and the firing temperature in determining the brick quality. Results showed that the brick weight loss in ignition was mainly attributed to the organic matter content in the sludge being burnt out during the firing process. With upto 20% sludge added to the bricks, the strength measured at temperatures 960 °C and 1000°C met the requirements of the Chinese National Standards. Toxic Characteristic Leaching Procedure (TCLP) tests of bricks also showed that there is low metal leaching.

The study conducted by Chihpin et al. (2001) investigated [5]the use of sludge as partial substitute for clay in brick manufacturing. In this study, four different series of sludge and clay proportioning ratios were studied, which exclusively involved the addition of sludge with ratios 50%, 60%, 70% and 80% of the total weight of sludge-clay mixture. Each series involved the firing of bricks at 950°C, 1000°C, 1050°C and 1100°C, giving 16 different brick types. The physical properties of the manufactured bricks were then determined and evaluated according to Egyptian Standard Specifications and British standards. From the results, it was concluded that by operating at the temperature commonly practiced in the brick kiln, 50% was the optimum sludge addition to produce brick from sludge-clay mixture.

2 OBJECTIVE OF THE STUDY

The objective of this study is to identify the possibilities of using sludge obtained from effluent treatment plant [6] in HLL Lifecare Limited ; Peroorkada, Trivandrum as a brick material. The different engineering properties were also studied. The sewage sludge is having a typical composition leading to a preliminary property analysis[7].The bricks thus manufactured were subjected to compressive strength test and water absorption test and thus their suitability for construction purpose was examined.

3 NATURE OF THE EFFLUENT TREATMENT PLANT

The Effluent Treatment Plant (ETP) in HLL was installed for clear water discharge from production line since 1969. Present ETP can handle up to l000 kL/day of wastewater.The following are the components of the said plant:

3.1.Collection Tank/ Equalization tank

The function of the equalization tank is to collect effluent from the different streams and to keep uniform characteristics for the effluent stream. Effluents from various sections of the plant, which includes latex, filtrate from Nutsche filter, wash water and canteen effluent are collected in this tank. Four such collection tanks are installed to collect wastewaters from the three plants A, B and C.

3.2.Lime Mixing Channel

pH of the raw effluent ranges from 9-10. Hydrated lime, i.e., 1% solution of lime is therefore added to the effluent in order to make the pH 12. This enhances floe formation. Lime is allowed to flow into the channel under gravity.

3.3.$FeCl_3$ Mixing Channel

$FeCl_3$ reagent stored in Sintex tank is next transferred under gravity and is added to the effluent at the rate of 150-1000 mL/min. This neutralizes the pH and brings the pH level to 6-8.

3.4.Sludge Recirculation Sump

Sludge from secondary settling tank is to be fed to sludge recirculation sump by gravity. Sludge will be partially recycled back to the aeration tank. Balance portion will be send to sludge drying bed. It is cleaned once in a month.

3.5.Chemoxidation Tank

Overflow from secondary settling tank is fed to Chemoxidation tank. Diluted sodium hypochlorite solution is dosed for 24 hours (20 litre NaHOCl in 180 litre of water). General flow rate is maintained as 140-200 mL/min. Addition of NaHOCl oxidizes residual biodegradable organics. pH after dosing is maintained at 7-8.

3.6.Pressure Sand Filter

The clear overflow from the chemoxidation tank is pumped through two Pressure Sand Filters operated in parallel for removing any precipitated solids during Chemoxidation. Filter feed pumps are used for feeding the effluent to the pressure sand filter. The filter is backwashed every 20 minutes.

3.7.Treated effluent water collection tank

Overflow from sand filter is fed to final effluent water collection tank through a cascade. The overflow from the final treated water is discharged through the final outlet. pH of treated water is maintained at the range of 6-8 and recycled on hourly basis. The flow rate through final outlet is noted using V notch and calculated using the following relation:

$$Q=H^{5/2} x\ 1.4x\ 60x\ 60x24 \qquad (1)$$

where,Q- Discharge through the V notch in m^3/s

H- Height of the water flow through V notch in cm

While calculating the discharge using (1), height of water flow through V notch is maintained in the range of 6.5-12.5 cm.

3.8.Recycling of treated effluent water

40% of treated water [8] is used for gardening, toilet flushing, floor cleaning, ETP cleaning works etc. In addition to the above, treated water is supplied in tankers for gardening at Golf Club, Trivandrum.

3.9.Sludge Drying Beds

Solid cake from the filter press is transferred to sludge drying beds. Sludge from the other tanks during cleaning operation is also transferred to sludge drying beds. There are 6 cells in sludge drying beds. After filling each cell, sludge is taken to the next cells. This process is separated till the sludge covers the entire cells in drying cells. Filtrate from the bed is allowed to enter aeration tank for further treatment.

4 STUDY SPECIMENS-BRICKS

Brick is one of the oldest building materials and it is extensively used even at present because of its durability, strength, reliability, low cost, easy availability etc. Bricks are obtained by moulding clay in rectangular blocks of uniform size then by drying and burning these blocks in brick kilns .The use of typical sludge is the focal point of this study[10].The study conducted at water treatment plants had shown that the percentage of sludge in brick manufacture can be progressively increased to desired strength with addition of special additives[10,11,12].Use of flyash is being studied here.

5 MATERIALS AND METHODS USED

The sludge subjected to drying for a period of two weeks was collected from the effluent treatment plant of HLLLifecare Limited, Peroorkada.The different engineering properties studied are as follows:

5.1.Materials

- Sludge(<2.36mm)
- Clay (<2.36mm)
- Sand(<2.36mm)

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5.2 Moisture Content

Moisture content is the ratio of weight of water present in the sludge to the weight of dry sludge.It was calculated as per IS 2720 (Part II),1973.[13]

Dish No.	1	2	3
Weight of Dish (Wl) g	48.22	34.04	28.18
Weight of dish+ wet sludge (W2) g	77.71	60.84	48.65
Weight of dish + oven dry sludge (W3) g	60.21	44.31	35.49
Weight of oven dry sludge (W3-W1) g	11.99	10.27	7.31
Weight of water (W2-W3) g	17.5	16.53	13.16
Moisture content(%)	145.95	160.95	180.03

Table 1:Observation for moisture content determination

$$\text{Moisture Content}=(W2-W3)/(W3-W1) \tag{2}$$

TheAverage moisture content was found to be 162.31%

5.3. Specific Gravity

Specific gravity of sludge is the ratio of weight in air of the given volume of dried sludge to the weight of equal volume of water at 4°C.

Specific Gravity of sludge=

$$(W2-W1) / ((W4-W1)-(W3-W2)) \tag{3}$$

Where,

W1=weight of dry pycnometer

W2=weight of pycnometer containing one-third sludge by volume.

W3= weight of pycnometer containing one-third sludge by volume + water to fill the pycnometer.

W4=weight of pycnometer fully filled with water.

Table 2: Observation for specific gravity determination

No.	1	2	3
Weight of bottle (g)	627	627	627
Weight of bottle + soil,W1 (g)	791	844.5	943
Weight of dry soil, W2 (g)	164	217.5	316
Weight of pycnometer + soil + water,W3 (g)	1558.5	1597	1630
Weight of pycnometer + full of water, W4 (g)	1521	1521	1521
Specific gravity	1.296	1.537	1.5266

Specific Gravity= 1.53

Brick moulds were properly oiled using furnace oil. The mixed sludge was then filled in brick moulds in 3 layers. Each layer was compacted with the compaction rod and the surface was finished with a trowel.

5.4.Drying

The bricks were removed from the mould immediately and were kept aside at room temperature for drying.

5.5.High Temperature drying in Oven

After one day the bricks were subjected to burning in a muffle furnace. The bricks were burned at a temperature of 1000°C for 2 days.

5.6. Testing

Standard tests as per IS Specification were conducted on bricks. The tests were conducted in the Strength of Materials Lab, Department of Civil Engineering, College of Engineering, Trivandrum.

6 RESULTS AND DISCUSSION

6.1.Number of bricks required

Three bricks each were made for conducting the compressive strength test as well as the water absorption test. With the varying percentage of sludge, three bricks each were required for each percentage. Six moulds of dimensions 19cmx9cmx9cm were used and therefore simultaneously 6 bricks could be made at a stretch.

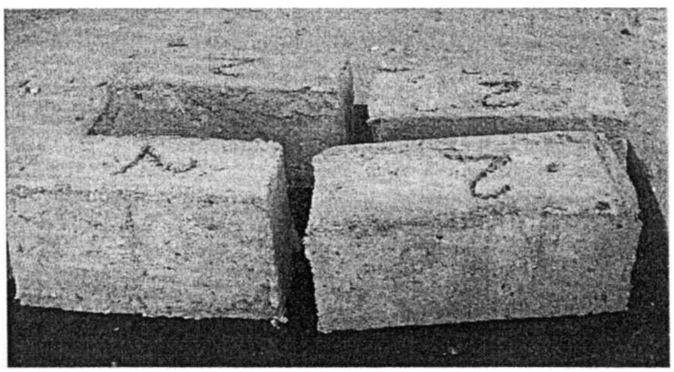

Fig 1.Brick specimens

6.2. CASE 1- Variation in brick properties of bricks with respect to change in percentage of sludge, clay and sand

The sludge, clay and sand were thoroughly crushed and sieved through 2.36mm sieve. Two sets of bricks were made in the proportions 2:2:1 (sludge: clay: sand) and 1:3:1 (sludge: clay: sand).

TABLE 3.
PROPERTIES OF CASE I BRICKS

Brick specimen	Proportion (sludge:clay:sand)	Water Absorption(%)	Compressive Strength(N/mm^2)
1	2:2:1	37	1.5
2	1:3:1	24	0.93

6.2.1 Compressive strength of Bricks

After conducting the compression test on the brick specimens a graph was plotted showing the effect of percentage of clay and sludge on compressive strength of brick as shown.From the graph it was observed that the compressive strength decreased with increase in the percentage of sludge.After conducting water absorption test on the two set of bricks a graph was plotted showing the effect of percentage of clay and sludge on water absorption .From the graph it was observed that the water absorption of the bricks increased with increase in the percentage of sludge.

6.3. CASE 2 - Variation in brick propertiess under varying percentage of sludge and clay

Since sand could not melt at the temperature available in the oven, it failed to bind the other materials properly. Thus we removed sand later on and introduced Case II in which bricks were prepared using sludge and clay only. Sludge and clay were crushed, sieved through 2.36mm sieve and mixed in different proportions. The sludge: clay proportions used were 2:3, 1:4, 4:1, 3:2 and 1:1 respectively. Reference bricks were also made using 100% sludge and 100% clay. [14]

TABLE 4
PROPERTIES OF CASE II BRICKS

Brick specimen	Proportion (Sludge:clay)	Waterabsorption (%)	Compressive strength (N/mm^2)
1	2:3	22	1.8
2	1:4	19	1.585
3	4:1	37	1.413
4	1:0	41	1.18
5	0:1	11	1.62
6	1:1	29	1.68
7	3:2	30	1.36

6.4. CASE 3- Variation in brick properties with addition of cement

Cement is used as an additive to improve the properties of the bricks. Cement is a binder, a substance that sets and hardens independently, and can bind other materials together [15]. The composition of sludge: clay is taken as 1:4 that is 20% sludge and the remaining 80% clay. This composition was taken as water absorption at this composition as observed in the above cases was within the permissible limits. To this cement was added. Three sets of bricks were made in this case, each set with a different percentage of cement. Cement was added in 5%, 10% and 15% of the total weight of sludge and clay to a set of bricks. Each set comprises of 3 bricks each. Thus total 9 bricks were made.

6.5. CASE 4- Variation in brick properties with respect to flyash addition

Flyash is used as an additive in making bricks. It was added in the same way as cement was added in case III. Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Three sets of bricks were made with varying percentages of flyash.

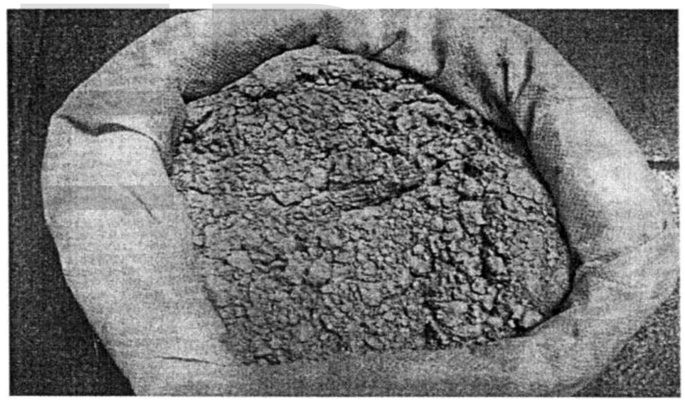

Fig 2. Sample of Fly ash used

TABLE 5
PROPERTIES OF CASE III BRICKS

Brick Speci men	Proportion (sludge: clay)	Percentage of fly ash added (%)	Water Absorp-tion (%)	Compressive Strength (N/mm^2)
1	1:4	5	19	1.6
2	1:4	10	17	1.89
3	1:4	15	14	2.3

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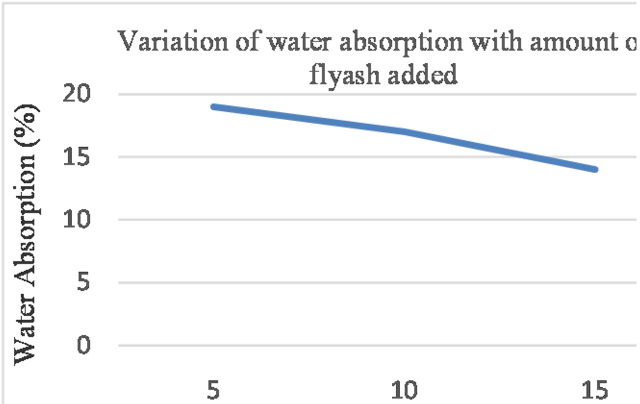

Fig 3. Variation of water absorption with amount of flyash

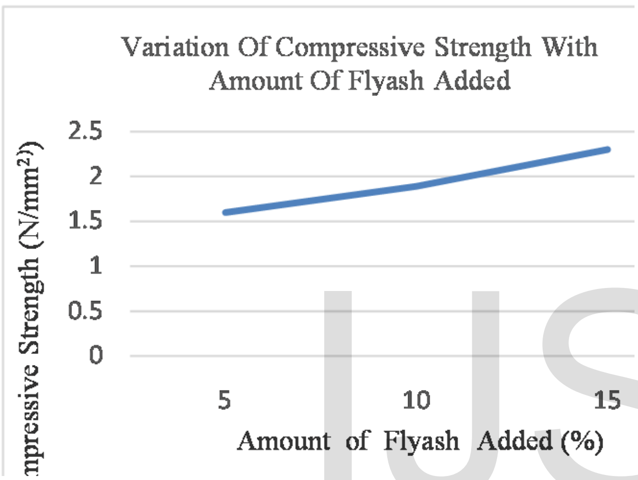

Fig 4. Variation in compressive strength with amount of flyash

6.6. CASE 6- Variation in brick properties with respect to sisal fibre addition

Sisal fibres made from the plant Agave sisalana is used for improving the strength of the bricks of proportion 1:4 sludge: clay. Some amount of sisal fibre each of length 5cm was added into the mix and the bricks were moulded after thoroughly mixing the fibres with the sludge-clay mix. Three bricks of the mix were made and the tests for the same were conducted.

Fig 5.Sample of sisal fibre used

TABLE 6
PROPERTIES OF CASE IV BRICKS

Brick specimen	Proportion(sludge:clay)	Water Absorption (%)	Compressive Strength (N/mm^2)
1	2:3	21	1.6
2	1:4	20	0.62
3	1:1	30	1.4

The shearing resistance of bricks was found to be considerably high when sisal fibres were added.

7 CONCLUSION

Sludge produced in the plant was effectively used in manufacture of bricks and the quantity of waste generated was minimized[16].Different engineering properties of the sludge such as specific gravity and moisture content were studied. Specific gravity of sludge was obtained as 1.53 while moisture content was observed to be 162%.Different conditions affecting the strength of bricks were studied. It was seen that when percentage of sludge was increased in the mix, water requirement as well as water absorption of the bricks increased. But at the same time, compressive strength of the brick decreased. But on the addition of cement and flyash, the properties of the bricks improved. Eventhough the shearing resistance of the bricks improved on the addition of sisal fibres, there was no effect on the water absorption and compressive strength of the bricks. Thus it could be concluded that the sludge alone cannot be used for brick manufacture. But the properties of the bricks have shown considerable improvement after the addition of stabilizers like cement and flyash.The various effects [17] of sludge are to be considered in future studies and its health and environmental effects are to be taken into account.

8 SCOPE OF FUTURE STUDY

8.1 Mixing

In this study hand mixing was done to mix the ingidients of brick together. The strength of bricks might be improved if a pug mill was used for mixing.

8.2 Binding

Different other kind of additives like coir fibres, lime, charcoal husk etc shall be tried to improve the strength of the bricks.

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