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Research Article

Utilization of Polluted Dredged Sediment for Making of Bricks

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Abstract

The present study conducted to evaluate the feasibility of the production of bricks using dredged lake sediments, which is seriously polluted with industrial effluents. Hussain Sagar, Hyderabad, is an identified as one of the most polluted water body in India. Solidification and Stabilization is main principle behind this waste management. Two types of mix proportions were used to cast the test specimens, Type-I bricks are prepared using sediment as sole raw material and Type-II are prepared using sediment and fly ash compositions of 75% and 25% respectively. The bricks are fired at temperatures between 500°C to 700°C. S/S products were cured for 28 days, the strength of the brick specimens, the leachability of heavy metals and the mineralogical phase of the produced bricks were studied based on X-ray diffraction spectroscopy, Thermo gravimetric-Differential Thermal Analysis, Unconfined Compression Strength, Toxicity characteristics leaching procedure tests and water absorption test . All the specimens were perceived to be sufficient in achieving the compressive strength ranged from 4.7 to 6.2 N/mm2. Results of this study demonstrate that production of fired bricks is a promising and achievable productive use of Hussain Sugar polluted dredged sediment.

INTRODUCTION

Healthy lakes and their shores not only provide us with a number of environmental benefits but also influence the quality of our life and strengthen our economy. Improper planning of Human settlements and industrialization nearby lakes create violence to the future generations. One of the major impacts of urbanization and industrialization on the lake was in the form of poor water quality due to interruption of pollutants. Since the beginning of last century, while the lake basin was undergoing rapid change, since very little attention was paid to this vital issue. Thus, failure of Lake Basin management is due to improper sewage system and industrial waste disposal infrastructure, which are responsible for rapid degradation of the Lake Environment as well as ground water quality.

Human settlements surround the Hussain Sagar Lake in Hyderabad is increased due to tremendous urbanization and industrialization [1]. The settlements and their associated activities generates sewage and industrial effluents, which one being received as input to the Hussain Sagar lake. Due to this the lake quality was adversely affected after 1970's. Kukatpally and Dullapally sub basins are the main intake industrial pollutants of the lake. The range of products manufactured by 300 odd industrial units include chemical reagents, organics, pharmaceuticals, drugs, bio-chemicals, synthetic chemicals, detergents, aircraft batteries, distillation products, alloys and rubber products. Because of this the lake was receiving a cocktail of toxic components (pollutants) [2]. The average run off during normal year into the lake is about 28-33 m^3/year [3].

The solid materials and silt along with heavy runoff, decreases the depth of the lake further decrease in the infiltration capacity followed by ground water table getting down. Earlier the depth of the lake is around 12.2M, which gradually reduced to about 5.02M as on today, probably because of severe siltation and sedimentation. In 1992, Environmental Protection Training and Research Institute (EPTRI) has estimated an inflow of settleable solids with the concentration of 280 mg/l in dry weather inflow of 25.73 m^3/year, the maximum siltation would be 3602 tons per year assuming only 50% of the solids were settled and the study further added that there is an inflow of 18 tons of phosphorus and 70 tons of nitrogen along with settleable solids [1]. To improve the lake water quality by preventing pollutants entering into the lake from both point and non-point sources of pollution, as well as removal of elemental enriched poll sediments from lake were under process [4].

Generally the lake sediment shows a strong tendency for adsorption of contaminants, particularly inorganics and heavy metals. Thus, analysis of these sediments constitutes a rapid way of obtaining time integrated information concerning a range of sedimentalogical variables [5].

In recent decades several types of waste materials have been assessed as raw materials for brick making, for example lightly contaminated harbour sediments [6-8], waste bricks [9], limestone dust and wood sawdust [10], processed waste tea [11], reservoir sediments mixed with fly ash [12], dried sludge collected from industrial waste water treatment [13-15], incinerated sewage sludge ash [16-18], fly ash [19], granite sawing waste material [20], water treatment residual with excavation waste soil [21], steel dust [22] and kraft pulp production residues [23]. As a consequence, it is imperative to develop a new alternative for conventional solid soil bricks. Fortunately, preparation of hollow bricks based on the solid waste [24], especially fly ash [19,20,21,22,25] has gained fast development in recent years.

In present study the dredged sludge is converted in to an eco-friendly value added product, where the industrial wastes by product are also incorporated. The characteristics of the bricks will be evaluated using Toxicity characteristics leaching procedure (TCLP), Bulk density, Unconfined Compressive Strength (UCS), Water adsorption, X-ray diffraction spectroscopy (XRD), and Thermo gravimetric-Differential Thermal Analysis (TG-DTA).

MATERIALS AND METHODS

The dredged sediment was obtained from the Hussain Sagar Lake Figure 1, Hyderabad. Fly ash is collected from a coal firing industry.

Characterization of sediment

The physico-chemical characters of the sediment were given in the Table 1. Analysis carried using American Society for Testing and Materials (ASTM), American Public Health Association (APHA), and Atomic Absorption Spectrometer instrument GBC scientific model SensAA.

Experimental procedure

The raw materials are blended evenly and subjected for moulding with the dimension of 100mm ×50mm×50mm. Two types of bricks are prepared with sediment alone and sediment with fly ash (Table 2). These moulded specimens are kept for drying at room temperature. The dried specimens are kept at different firing temperatures in the range of 500-700°C (i.e., 500, 600 and 700°C) for 6 hrs using muffle furnace along with, bricks also prepared for without heat treatment B-I and B-II (Table 2). Physical and mechanical properties of the above bricks are evaluated in terms of Compressive Strength test (BIS (IS 4031) and Water Absorption test (BS 3921: 1985) respectively according to ASTM methods**.** Chemical composition is carried by XRD and thermo gravimetric behaviour of the S/S product is observed by TG-DTA. Toxic characteristic leaching procedure (TCLP) as described in United States Environmental Protection Agency (USEPA)-1311 are performed to investigate the leachability of metals from the above bricks with and without heat treatment [18-26].

Reaction product analysis

X-ray Diffraction (XRD): The crystalline structure of the brick, which affords better understanding on the reaction products, was analyzed by X-ray diffraction (XRD). XRD scans of brick material is performed with Bruker D8 advanced X-ray diffractometer operated at 40 kV and 30 mA (CuK-alpha radiation

Table 1: Physico-chemical characterization of Hussain Sagar sediment.

S. No	Parameter	Results
1	Colour	Black
2	State	Solid
3	pH	7.93
4	Moisture content (%)	9.64
5	Density (g/cm^3)	1.6
7	Chlorides as Cl (mg/kg)	0.69
8	Organic matter (%)	13.02
9	Zn (mg/Kg)	180
10	Fe (mg/Kg)	280
11	Ni (mg/Kg)	15.5
12	Co (mg/Kg)	19
13	Cd (mg/Kg)	5.15
14	Cu (mg/Kg)	111.55

Table 2: Composition of fired bricks.

S. No.	Compounds	Type-I	Type-II
1	Sediment	100%	75%
2	Fly ash	-	25%

(λ=1.5418 A^0)) in the range 20–80^0 2θ at scanning rate of 1^0 2θ per minute.

Thermo gravimetric Analysis (TGA): The thermal behaviour and weight loss of the sample was determined using TGA. TGA of the sample was done by S-II EXSTAR-6000, TGA-6300 thermal analyzer. Sample loaded in aluminium container and heated to 800 °C at the rate of 2 K/min with air circulating at a speed of 150 ml/min.

Toxicity Characteristic Leaching Procedure (TCLP): Toxicity Characteristic Leaching Procedure (TCLP) of S/S sludge bricks (waste create bricks) were conducted as per the standard procedures described by USEPA 1996. The heavy metals were analyzed by Atomic Absorption Spectrometer (AAS) GBC scientific model SensAA.

Unconfined Compression Strength (UCS): UCS of unfired cubes were measured by compression testing machine as per BIS

Figure 1 Sediment dredging from Hussain Sagar Lake, Hyderabad.

specification code (IS 4031) (IS: 1077-1992). ELE International model 36-3280/01 was used testing.

RESULTS AND DISCUSSION

The preapared brick specimens shown in the Figure 2.

Sediment chemical analysis

Sediment compositon was given in the below Table 3, which involved to improve the quality of the bricks it is in turms of compressive strength.

Water absorption test

According to ASTM, the water absoption test as determined by submersion of bricks in water for 24hrs must be less than 18% [26]. In the present study, water absorption of the all bricks produced at each firing temperature were represented in Figure 3 observed to meet the standard critirea. The water absorption of type-I bricks are observed to be 11.25, 11.0 and 10.2 while for type-II bricks it has been observed to be 10.5, 10.4 and 7.5 made at temperatures 500^{o}C, 600^{o}C and 700^{o}C respectively. Which revealed the normal porous nature of the bricks produced. Water absorption decreased significantly when the temperature increased from 500-700^{o}C due to the formation of amorphous phase of brick at high firing temperatures [20-26].

Density

Density of the clay brick depends on specific gravity, method of manufacture, and degree of burning. Density of burned clay bricks usually exceeds 1.6gm /cm^3, averaging 2.0gm/cm^3. In this study, density remarkably improved by firing at higher temperatures. When density of a brick decreases its strength and heat conductance decreases, and water absorption increases, When brick exihibits a larger pore size, the mixture absorbs more water resulting in a lower density [26]. The intial density of sediment is 1.6gm/cm^3. The density of Type-I bricks varied from 1.7gm/cm^3 to 2.0gm/cm^3 and for Type-II bricks 1.8 to 1.5gm/cm^3 at 500^{o}-700^{o}C respectively. Density increased linearly as firing temperature was raised for Type-I bricks (500-700^{o}C). This finding is closely related to the quantity of water absorbed at this point , and the decreasing in porosity. When the mixture absorbs more water, brick exhibits a larger pore size, resulting in a lighter density. Firing time longevity (8hrs) had no effect on density of clay bricks [24- 26].

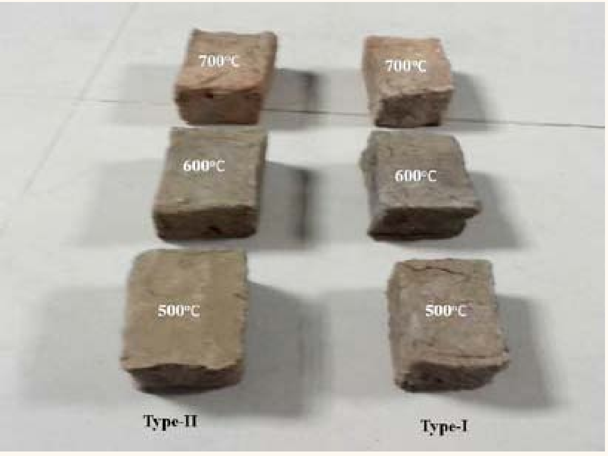

Figure 2 Bricks Prepared by Sediment.

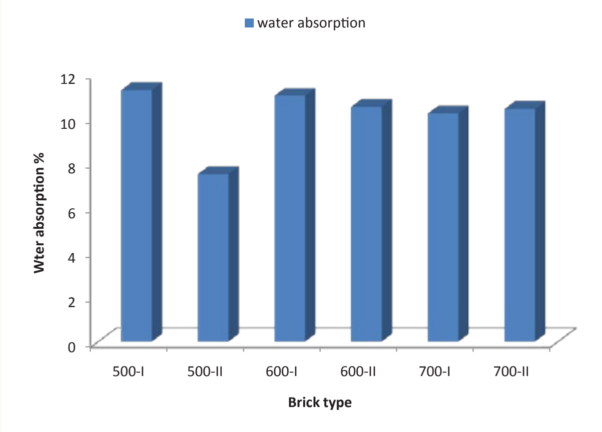

Figure 3 Water absorption test of the fired bricks.

Evaluation of physical engineering property of the fired brick samples by compressive strength

Unconfined compressive strength (UCS) is one of the important parameter, which evaluates the cohesive property of the Solidification and Stabilization (S/S) product. After completion of heat treatment of the bricks, The Compressive strength of the sediment bricks are measured and represented in Figure 4. The compressive strength of the Type-I bricks have been observed to be 3.6N/mm^2, 3.9N/mm^2 and 4N/mm^2 whereas Type-II bricks have been observed to be 4.78N/mm^2, 5.12N/mm^2 and 6.2N/mm^2 and the unfired bricks i.e., BI and BII bricks have been observed to be 1.26N/mm^2 and 2.24N/mm^2 at the temperature variation of 500^{o}C, 600^{o}C and 700^{o}C respectively. The fired specimens had met the minimum brick compressive strength According to Bureau of Standards (IS: 12894-2002).

TCLP leaching studies

Metal Leaching test was conducted to investigate the immobilizing ability of S/S products [27]. The variable metal concentrations in the leachate of the unfired and fired bricks (S/S) were reported in Table 3. Results from TCLP method showed insignificant levels of heavy metals and comply with the concentration limits set by EPA(2005) (DC: USEPA, 1994). It is observed that Ni, Fe, Cu and Zn have leached from unfired (B-I and B-II) and fired brick samples, but the concentrations are much less than those of the EPA regulated TCLP limits.

Reaction product identification by XRD in the S/S matrix

X-ray diffraction (XRD) pattern affords better understanding on the reaction products. The crystalline phases of type- I, II bricks fired at 700^{o}C are presented in Figure 5 it indicates the presence of Quartz, Anorthite, Kaolinite and Aluminium silicate in type-I bricks, where in type-II bricks indicates the presence of

Table 4: Concentration of Heavy Metals in Leachate (TCLP).

S. No	Brick type	Temperature (^{0}C)	Final concentration			
			Ni	Fe	Zn	Cu
1	B-I	-	0.53	1.5	1.6	0.11
2	B-II	-	0.52	1	0.6	0.11
3	Type-I	500	0.4	1.35	0.60	0.12
4	Type-II	500	0.3	0.75	0.09	0.08
5	Type-I	600	0.4	1.155	0.50	0.09
6	Type-II	600	0.3	0.5	0.04	0.06
7	Type-I	700	0.4	1.1	0.20	0.07
8	Type-II	700	0.2	0.5	0.01	0.06

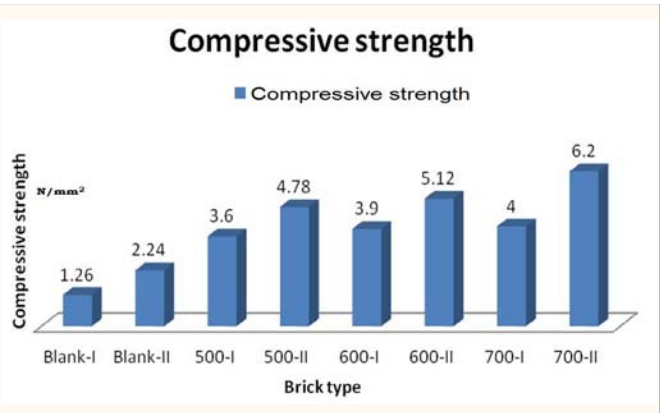

Figure 4 Compressive strength of bricks after 28 days.

Quartz, Anorthite, Kaolinite, potassium aluminium silicate (Table 4). The main mineral phase of the urban river dredged sediments is quartz (SiO2) [28]. The presence of anorthite in the XRD pattern of the fired specimens demonstrated that the firing process was reached the equilibrium state [28]. High crystallinity of anorthite had the highest compressive strength value; it could be noticed in Type-I and II samples. The formation of quartz phases observed to be more than the other crystals. In most of the cases, firing involved to enhance the compressive strength since decreasing porosity which reduces the crack formation [28,29].

Thermo Gravimetric Analysis (TGA)

The thermal behaviour of the S/S product has investigated by TGA and shown in Figure 6 (Type-I and Type-II). Both the brick samples have shown weight losses at 3 elevated temperatures. Weight loss observed at first elevated temperature in Type-I and II bricks at the temperature of 130^{0}C, it is 3.7% and 3.4, at second elevated temperature is 6.24%s and 5.1%, finally at third elevated temperature the weight loss is recorded as 4.4 and 3.8 % respectively. The clay started losing water when it was heated up to 250^{o}C. The big changes between 500^{o}C to 570^{o}C where the dehydroxylation of clay minerals occurred [28,29].

CONCLUSION

The results of study shown that compressive strength of Type-II bricks are more, when compare to Type-I and unfired bricks. Fired bricks showing more strength than unfired bricks. Both type of the fired bricks achieved the minimum compressive strength required BIS standards. Water absorption and density of Type-II bricks is less than Type-I bricks. Metal leaching in fired bricks is less than unfired bricks. Therefore, the sediment from Hussain Sagar Lake has a potential to reuse as construction materials for different applications. This study concludes that the production of construction materials can be replaced with lake sediment and industrial by products in some extend compositions.

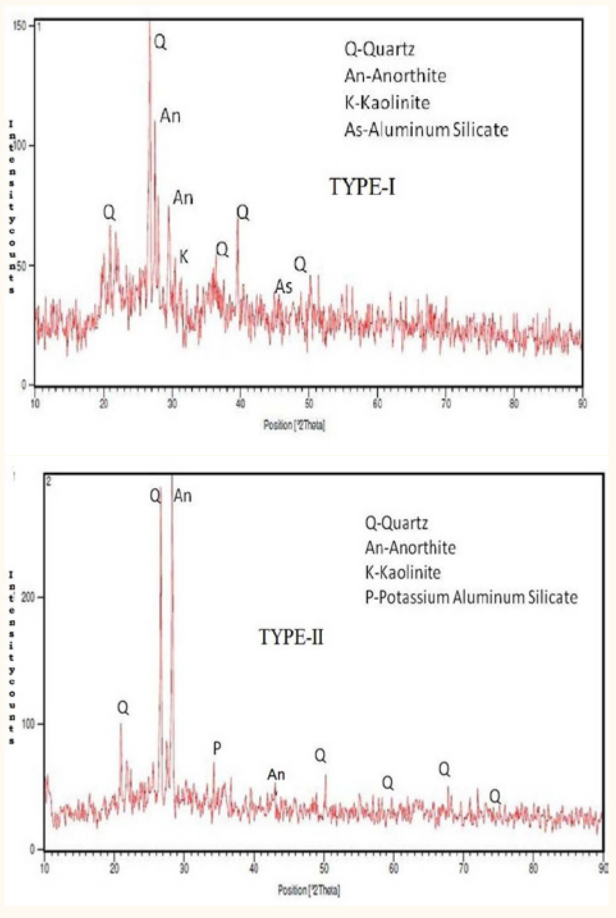

Figure 5 XRD pattern of the fired brick.

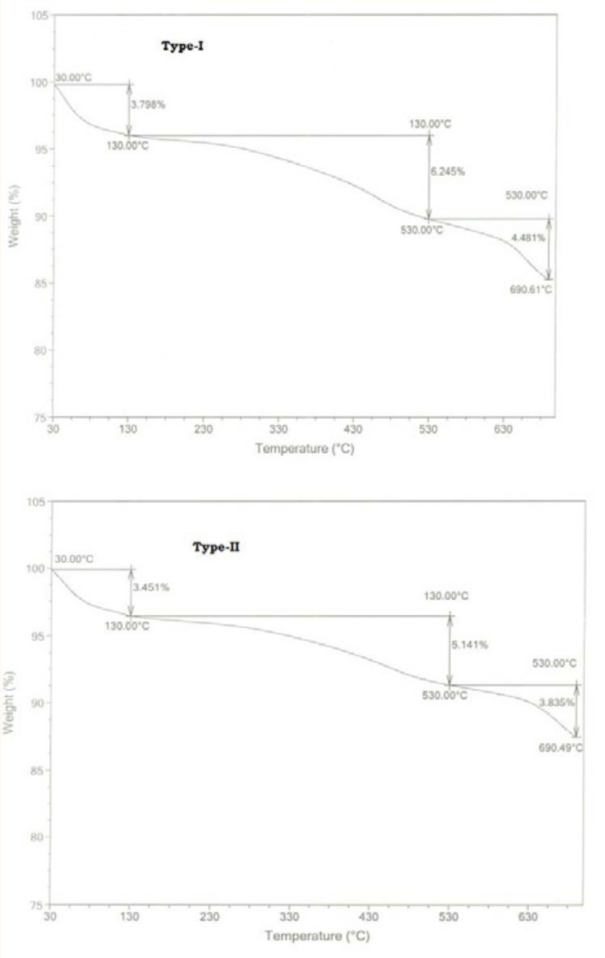

Figure 6 TGA analysis of fired brick Samples.

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