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Characterization of automobile effluent treatment plant sludge: Its utilization in construction materials

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HIGHLIGHTS

- Characterization of automobile ETP sludge.
- Effect of ETP sludge on the properties of blocks, tiles, bricks studied.
- Leaching test revealed that concentration of leached metals is quite low.
- ETP sludge up to 35% can be utilized for making construction materials.

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ABSTRACT

In this study, the characterization and influence of automobile effluent treatment plant sludge on the properties of cement–sludge binder, paver blocks and flooring tiles is discussed. The engineering properties of burnt clay bricks prepared by partial replacement of soil with automobile sludge at 900 °C and 1000 °C were evaluated. The results of leaching studies, conducted for tiles/paver blocks samples using Toxicity Characteristic Leaching Procedure, revealed that the concentration of leached metals is quite low than the limits specified in Indian Standard. These results amply demonstrated that automobile sludge up to 35% can be utilized for making building components.

1. Introduction

In many developing countries, the constantly rising demands of the housing and construction sectors have led to acute shortage of building materials. Serious efforts have been made to improve productivity, efficiency and performance of the traditional materials and to utilize industrial wastes like fly ash, granulated blast furnace slag, gypsum, demolition wastes etc. in the building materials [1–6] and for various other applications [7–10]. The utilization of industrial wastes in construction materials is quite desirable for the sustainable development of the economy and society.

In order to reduce the environmental impact of construction materials, the incorporation of alternative materials is becoming an important option in the construction industry. In India, several industries generate effluent treatment plant (ETP) sludge as a waste of effluent and sewage treatment plant during the treatment process comprising of chemical coagulation, flocculation and liquid/solid separation. This sludge degrades the environment and poses hazards to both human and animal life, thus causing concerns for their disposal. Due to the indiscriminate land disposal trends, large areas of fertile land have become barren and unproductive for agricultural purposes. Efforts are, therefore, being made throughout the world to effectively recycle these industrial wastes in eco-friendly construction materials.

The cementitious systems based on ETP sludge obtained from various sources have been investigated by various researchers [11,12]. Balasubramanian et al. [13] have suggested that the use of textile ETP sludge up to a maximum substitution of 30% for cement may be possible in the manufacture of non-structural building materials. Saxena et al. [14] investigated the use of copper tailings up to 50% replacement of clay in the manufacture of bricks and Sengupta et al. [15] reported the preparation of bricks in commercial plant using 30% petroleum ETP sludge. Saikia et al. [16,17] reported that the hydration characteristics of metakaoline–lime system enhanced by cocalcining kaoline with petroleum ETP sludge and the properties of blended cement was improved by

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Table 1
Physical and chemical analysis of automobile ETP sludge.

Property	Value
Physical parameters	
Colour	Light grey
Physical state at room temperature	Semi solid
Moisture (%)	28.5
Total solids (%)	70.82
Volatile solids (%)	29.31
Fixed solids (%)	41.51
pH	7.27
Bulk density (g/cc)	0.91
Chemical parameters (%)	5.5
Insoluble residue	
SiO_2	12.9
$Al_2O_3 + Fe_2O_3$	16.9
CaO	7.2
MgO	3.3
SO_3	3.8
Organic matter	30.5
LOI	19.7

replacing 20% cement with cocalcined kaoline-sludge containing up to 30% sludge.

ETP sludge, a waste of effluent and sewage treatment plant is produced in India to the tune of 3.0 million tonne per annum from the automobile industries. This huge amount of abandoned automobile sludge is not only thrown away without any commercial return but also the impurities of inorganic salts and toxic metals in the automobile sludge pose a threat to environment and thus, there is a growing need to find alternative solutions for automobile sludge management. The use of automobile ETP sludge in construction materials could serve as an alternative solution to disposal and reduce pollution. Therefore, a systematic study was undertaken to utilize automobile effluent treatment plant (ETP) sludge in construction materials. The burnt clay bricks were also made by partial replacement of soil with the automobile ETP sludge. The characterization of automobile sludge and its effect on engineering properties of cement–sludge binder, pre-cast concrete pavers blocks, flooring tiles and bricks are presented in the paper. The leachability studies are also reported.

2. Materials and methods

2.1. Raw materials

2.1.1. Automobile ETP sludge

The sample of automobile ETP sludge procured from the M/s Tata Motors Ltd., Pantnagar was analysed for various chemical constituents as per the standard test procedures [18,19]. The mineralogical characterization was studied by X-ray diffraction technique (XRD) (Rigaku D-Max 2200). The results of physical and chemical analysis of automobile sludge are given in Table 1. The automobile sludge was neutral in character as indicated by pH and its fineness modulus was 3.2.

2.1.2. Soil

The soil sample was dried and evaluated for various parameters like chemical, mechanical, plasticity properties and grain size analysis as per the test procedures mentioned in standard [19]. The characterization of soil is given in Table 2. The mineralogical and morphological behavior of soil was studied by XRD and Scanning Electron Microscopy technique (SEM) (LEO 438 VP, UK).

2.1.3. Cement

The chemical composition and physical properties of Ordinary Portland cement (OPC) used for making cement-automobile ETP sludge binders, paver blocks and tiles are given in Table 3.

2.1.4. Aggregates

The physical and mechanical properties of fine aggregate (passing 4.75 μ IS sieve) and coarse aggregate (particles passing 10 μ IS sieve and retained over 4.75 μ IS sieve) are tested as per IS 2386 [20] and given in Table 4.

2.2. Preparation of cement-automobile ETP sludge binders

The mix composition of cementitious binders prepared by mixing the OPC with automobile sludge in different proportions designated as E1, E2, E3 and E4 are given in Table 5. The mix compositions E1, E2 and E3 have $Ca(OH)_2$: 2% and $CaCl_2$: 0.5% whereas E4 has no activator. The automobile sludge binders were tested for different properties as per the methods specified in Indian Standard [21].

2.3. Preparation of flooring tiles/concrete paver blocks/soil sludge bricks

The flooring tiles of size 150 × 150 × 25 mm and concrete paver blocks of size 250 × 150 × 65 mm were prepared using cement, coarse natural aggregate, fine aggregate, ETP sludge and activators in two layer system. The mix composition of flooring tiles is given in Table 6. Hydraulic pressure of 50 tons was applied for 30 s and after releasing the pressure, the tiles/blocks were taken out and demoulded. These tiles/blocks were then kept under moist hessian cloth for 28 days and dried at 50 °C for 2 days. The thickness of top layer lied in the range of 6–8 mm. The tiles and blocks were tested for physical properties as per Indian Standards [22,23].

The burnt soil–sludge bricks of size 228 × 114 × 76 mm were made by replacing soil with automobile sludge up to 35% (on dry weight basis). Experimental bricks were dried in sun and subsequently fired in electric furnace at 900 and 1000 °C for 4 h and then, monitored for compressive strength, water absorption and bulk density as per the standard test procedures [24].

2.4. Testing

The initial and final setting times of cement-automobile ETP sludge binders were determined using a Vicat needle as per the Indian standard [21]. The sludge binders were cast into 50 mm cubical molds at normal consistency. The samples were cured under water at 27 ± 2 °C for different hydration periods up to 28 days. The compressive strength of cubes before and after drying at 50 ± 2 °C for two days of respective hydration periods were determined and compared. The average value of compressive strength of three specimens of automobile sludge binders was within 5% variation level of the arithmetic average. The bulk density in kg/m^3 was calculated by dividing the weight of the specimen by the overall volume of the cube. The soundness of binder samples was tested by Le-Chatelier Clamp expansion test as per the method described in IS 6909 [25]. The water absorption was tested according to IS 2542 [26].

Table 2
Characterization of soil.

Chemical (%)		Mechanical analysis (%)		Plastic properties		Particle size (%)	
Insoluble residue	0.36	Clay	24.0	Liquid limit	27	Above 4 mm	Nil
SiO_2	64.5	Silt	34.4	Plastic limit	15	Above 2 mm, below 4 mm	1.00
Al_2O_3	18.0	Sand	41.5	Plasticity index	12	Above 1 mm, below 2 mm	0.60
Fe_2O_3	3.1			Activity co-efficient	0.5	Passing 1 mm	98.4
CaO	3.7						
MgO	2.7						
$CaCO_3$	2.4						
Organic Carbon	0.74						
Loss of ignition	4.5						
pH	7.6						