ABSTRACT

The rapid pace of urbanization and industrialization necessitated setting up of large number of coal based Thermal Power Plants in the country to meet the energy requirements, resulting in a huge production of fly ash. Fly ash, a waste product of Thermal Power Plants is generally disposed off in vicinity of the plants as a waste material covering several hectares of valuable agricultural land. This affects the ecology of land, water and air in the region. The Indian Government enacted a law in October, 2005 stating that a minimum of 25 percent fly ash must be used in the manufacturing of clay bricks for use in construction activities within a 50 km radius of coal based Thermal Power Plants. There were also restrictions on the excavation of top soil for the manufacture of bricks. This necessitates effective utilization of this accumulated waste material.

The electroplating industries are one of the oldest industries. These industries discharge highly toxic wastes, which include heavy metals and chemicals like cyanide. According to a report, in the year 2006 about 7,00,000 electroplating units were operating in India, out of which about 5000 units are located in Aligarh. The wastewater generated in Aligarh by lock industries, specially electroplating industries is around 250 million litres per day.

The present investigation attempts to explore the possibility of best utilization of the these two industrial wastes viz., fly ash and electroplating waste sludge, after converting them into a non hazardous material through an economical process, leading to an effective waste management applications such as, construction products and structural fill material etc.

Fly ash, procured from Harduaganj Thermal Power Plant, Harduaganj, 16 km from Aligarh, India, was used as the test material. This fly ash is classified as Class F type which is having low pozzolanic properties. The fly ash resembled with the particle size of silts and classified as ML.

Electroplating waste sludge was collected in the form of filter cake from one of the electroplating industries in Aligarh City, India, in which Nickel, Chromium, Zinc and ...
Cadmium plating were done, associated mostly with lock and other allied industries. The waste sludge comprises of 70% solid waste and 30% waste water, having pH as 1.2, specific gravity as 1.022. The waste sludge was having enormous quantity of heavy metals such as Ni, Cr, Zn, Cd, Cu and Pb. The finely powered white coloured lime was used as precipitator for electroplating waste sludge. The cement used in this study was OPC-43 grade.

Compressive strength tests were carried out on 100×100×100mm cubes prepared with various combination of fly ash (FA)–waste sludge (S)–cement (C), at 7, 14, 21, 28 and 90 days of curing. The toxicity characteristics leaching procedure (TCLP) leaching tests were conducted on the samples at 28, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 and 365 days of curing. On the basis of compressive strength and TCLP leaching tests on various combinations of fly ash–waste sludge–cement mix, the most effective percentages of waste sludge was obtained in the range of 30% to 45%, whereas, for economical considerations the cement percentage was fixed as 8% in the fly ash for carrying out further studies. The maximum compressive strength was obtained for 60% to 55%FA, 30% to 45%S and 8%C composition. The average compressive strength for this range of mix has been observed to be 38.4 MPa at 28 days of curing.

The pH values of different mixes are found in the range of 6.9-10.9. The analysis by atomic absorption spectrophotometer (AAS) reveals that the concentration of heavy metals in the leachates is reduced by 97%-100%. When the experimental results of leaching are compared with US EPA (1992), EEC (1991) and DIN (1984), it is found that the heavy metals in the waste sludge were completely stabilized by fly ash–cement system.

On the basis of compressive strength and leaching tests, the range of most effective percentages of fly ash–waste sludge and cement were determined. Further, experimental investigations such as compaction tests, shear strength, California bearing ratio and plate load tests were carried out on the most effective percentages of fly ash, waste sludge and cement.

Compaction parameters, namely maximum dry density (MDD) and optimum moisture content (OMC), determined from Proctor compaction test serve as the benchmark
values to assess the quality of compaction. Therefore, these parameters need to be determined reliably. Standard and modified Proctor compaction tests were carried out keeping (i) 30%-50% of waste sludge and 70%-50% of fly ash; (ii) use of fresh/remolded samples; (iii) preconditioning period; and (iv) compaction energy as variable parameters.

The value of MDD of mix 55%FA+45%S was observed to be 13 kN/m³ which is about 40% more than MDD value (9.30 kN/m³) of fly ash under fresh condition. However, under remolded condition, the mix 60%FA+40%S gives highest value of MDD (13.40 kN/m³) which is 31% more than the MDD value (10.20 kN/m³) of fly ash.

For the estimation of MDD of fly ash and fly ash-waste sludge, a linear empirical model has been chosen in terms of optimum moisture content (OMC) and specific gravity (G). The proposed method has been validated for Harduaganj fly ash and fly ash-waste sludge mixes.

The undrained unconsolidated (UU) triaxial shear tests were conducted on cylindrical specimens of diameter 39 mm and length 84 mm, prepared for fly ash and different combination of fly ash-waste sludge-cement. The tests were carried out at different curing periods of 7, 28 and 90 days. The shear strength parameters and undrained shear strength of fly ash, fly ash-waste sludge and fly ash-waste sludge-cement combinations were determined.

The outcome of the shear strength test results was quite encouraging in terms of undrained shear strength and shear strength parameters. The maximum gain in shear strength was obtained at 90 days of curing for the mix 55%FA+45%S+8%C which is 2.48 MPa as compared to fly ash (0.10 MPa) for the same curing period.

The California bearing ratio tests were carried out on the fly ash and mix containing fly ash-waste sludge, fly ash-waste sludge-cement under fresh, 7, 28, and 90 days of curing. The CBR value of fly ash was obtained as 3.6% under fresh condition and 7.3% at 90 days of curing. The value at fresh condition is very low and undesirable for construction of pavement. On the other hand when fly ash was mixed with waste sludge and cement the CBR values increased significantly. The mix 47%FA+45%S+8%C gives maximum values of CBR (10.2%) under fresh condition, whereas, mix 42%FA+50%S+8%C gives the optimum value of CBR (43.7%) at 90 days of curing.
One of the effective utilization strategies for fly ash and fly ash-cement-stabilized waste sludge mix is to use it as a fill material to raise low lying areas. Bearing capacity and settlement are the required input for the design of foundations on such fills. However, it lacks database on the load-settlement behaviour of compacted fly ash and fly ash-cement-waste sludge fills, which can provide direct evidence on their performance as structural fills. To fill this gap, a comprehensive experimental study consisting of plate load tests on compacted fly ash, fly ash-waste sludge and fly ash-cement-waste sludge beds were planned. Plate load tests were carried out on the compacted beds of fly ash, fly ash-waste sludge and fly ash-waste sludge-cement. The tests were conducted by keeping (i) 90%, 95% and 100% relative compaction (ii) fresh and fresh submerged conditions (iii) aged (28 days) and aged (28 days) submerged conditions as variables of the tests. The load-settlement curves were plotted for fly ash and mix blends. The minimum load was obtained for fly ash under submerged condition. The test results show that the fly ash becomes very soft on submergence. On the other hand when the fly ash was mixed with waste sludge and cement, the load carrying capacity was found to improve to a great extent.

An analytical method has also been developed to estimate the settlement of footing resting on compacted fills taking into account the pre-consolidation stresses. The non linearity of load-settlement behaviour was appropriately modeled, on the basis of available plate load test data incorporated in the method. The method requires as input, the pre-consolidation stress and Young’s modulus of compacted mix of fly ash-waste sludge-cement. A comparison of load-settlement values observed in plate load tests and predicted values for the mix 47%FA+45%S+8%C, using the proposed method shows good agreement. Hence, the method proposed by for computing settlement of Dadri fly ash may suitably be used for mix containing Harduaganj fly ash, lime precipitated waste sludge and cement as well. This relationship may also be useful to the field engineers to check the reported load-settlement values for such types of mixes in the field.

Thus, fly ash mixed with waste sludge and cement and may find potential applications in road and embankment constructions with due regards for its strength characteristics, durability, longevity and environmental safety.