INTRODUCTION

1.1 GENERAL

Rapid industrialization has resulted in environmental pollution of gigantic proportions. The power generation in India through Thermal Power Plants has resulted in the massive production of fly ash, whose disposal has been a challenging task. The present day utilization of fly ash in India is at its infancy, and only an insignificant amount is being put to proper use. Also, most of the research carried out for utilization of fly ash has not been commercially and practically viable. A lot of work is expected to be done at the government level, especially by way of framing and implementing policy decisions like adequate incentive, concessions in taxes and duties, popularization campaigns, etc. Unless efforts of this nature are taken, the menace of fly ash will have disastrous effects on the ecology and environment. Fly ash is reported to cause ailments like allergic bronchitis, silicosis, and asthma. Besides, fly ash contaminates surface water and may also have an effect on underground water due to the presence of heavy metals like lead and arsenic (The Statesman 1998).

Nearly 73% of India’s total installed power generation capacity is thermal, out of that coal based generation is about 90%, and hence, the disposal of fly ash generated from the Thermal Power Plants has been a burning issue. The problem with fly ash lies in the fact that not only does its disposal require large quantities of land, water, and energy, its fine particles, if not managed properly, by virtue of their weightlessness, can become airborne, leading to health hazards. Most of the power plants now are facing shortage of dumping space for this waste material. Currently, 100 MT of fly ash is being generated annually in India, with more than 65000 acres of land being occupied by ash ponds. The production of ash is expected to be more than 150 MT by the year 2010. Consequently the World Bank has cautioned India that by the year 2015, disposal of coal ash would require 1000 square kilometers of land. Since coal currently accounts for 73% of total power production in the country, the World Bank has also highlighted the need for new and innovative methods for reducing impacts on
the environment (The Business Line 1999). Thus efforts have to be made for the
effective utilization of this accumulated waste. However, wastes are not completely
worthless if one goes by the claims of scientists at the international conference on
"Fly ash disposal and utilization" (Sinha et al. 2000). Fly ash, an oxide-rich waste
product of Thermal Power Plants, can be used as the raw material for different
industries. The pozzolanic character of fly ashes has been recognized and its use in
stabilization/solidification (S/S) of waste has been reported (Indraratna et al. 1991;
Conner 1990; Sophia and Swaminathan 2005).

MEF (2003), Government of India notification under Environment (Protection) Rules.
1986, were published in the Gazette of India, Extraordinary, Part II, Section 3,
Sub-section (ii) dated the 6th November, 2002 vide S.O. 1164 (E), has stated that
every construction agency engaged in the construction of buildings within a radius of
fifty to one hundred kilometres from a coal or lignite based Thermal Power Plant shall
use fly ash bricks or blocks or tiles or clay fly ash bricks or cement fly ash bricks or
blocks or similar products or a combination or aggregate of them in such construction
as per the following minimum percentage (by volume) of the total bricks, blocks and
tiles, as the case may be, used in each construction project, namely:

(i) 25 per cent by 31st August 2004

(ii) 50 per cent by 31st August 2005

(iii) 75 per cent by 31st August, 2006 and

(iv) 100 per cent by 31st August 2007

In respect of construction of buildings within a radius of 50 kilometres from a coal or
lignite based Thermal Power Plant the following minimum percentage (by volume) of
use of bricks, blocks and tiles shall apply:

(i) 50 per cent by 31st August 2004

(ii) 100 per cent by 31st August 2005

Meanwhile, various utilization patterns have been suggested at different levels. But
the effective and economical utilization of fly ash in bulk has an ample scope in the
field of geotechnical and highway engineering, where it can be used in the construction of road embankments, replacement of foundation soil, filling of low lying area along with hard crust construction (Basak et al. 2004).

The utilization of Fly ash is a four-fold issue:

- Beneficial conversion of wastes into wealth
- Savings in expenditure of its disposal
- Search for the technology to convert it into a much needed construction material
- Reduction in air or water pollution
- Though cement and concrete industries have been the largest users of fly ash, there is still a vast and greater potential in it for road making in rural or urban areas

Studies by health authorities at Harduaganj, District, Aligarh, India, show that a large number of people in the area are victims of lung infections and skin disease, caused by fly ash contamination in air and water. The authorities had built four ash ponds at Harduaganj, which have now been completely filled up. The fly ash is now being stored in new ash pond and getting scattered over the villages in the neighborhood. The effect of the ash is found on local animals and vegetation too. The cattles feeding the contaminated vegetation are victims of skin diseases and dental disorders. The population of birds and water animals is also decreasing in the area (The Financial Express 1999).

Growth of population, increasing urbanization, rising standards of living due to technological innovations have contributed to an increase in both the quantity and variety of solid wastes generated by industrial, mining, domestic and agricultural activities. Globally, the estimated quantity of wastes generation was 12 billion tonnes in the year 2002 of which 11 billion tonnes were industrial wastes and 1.6 billion tonnes were municipal solid wastes (MSW). About 19 billion tonnes of solid wastes are expected to be generated annually by the year 2025 (Yoshizawa et al. 2004). Annually, Asia alone generates ∼4.4 billion tonnes of solid wastes and MSW comprise 790 million tones (MT) of which about 48 MT (∼6%) are generated in India (Yoshizawa et al. 2004; CPCB 2000). In India, ∼4.5 MT of hazardous wastes are
being generated annually during different industrial process like electroplating, various metal extraction processes, galvanizing, refinery, petrochemical industries, pharmaceutical and pesticide industries (Asokan 2004; MEF 2003).

1.2 ADVANTAGES OF USING FLY ASH FOR GEOTECHNICAL APPLICATIONS

- Fly ash is a lightweight material, as compared to commonly used fill material (local soils) therefore, causes lesser settlements. It is especially attractive for embankment construction over weak subgrade such as alluvial clay or silt where excessive weight could cause failure.
- Fly ash embankments can be compacted over a wide range of moisture content and therefore, results in less variation in density with changes in moisture content. Can be compacted using either vibratory or static rollers.
- High permeability ensures free and efficient drainage. After rainfall, water gets drained out freely ensuring better workability than soil. Work on fly ash fills/embankments can be restarted within a few hours after rainfall, while in case of soil it requires longer period.
- Considerable low compressibility results in negligible settlement within the fill.
- Conserves the precious top soil, thereby protecting the environment.
- Higher value of California bearing ratio (CBR) as compared to soil provides, a more efficient design of road pavement.
- Pozzolanic hardening property imparts additional strength to the road pavements/embankments and decreases the post construction horizontal pressure on retaining walls.
- Amenable to stabilization with lime and cement
- Can replace a part of cement and sand in concrete pavements, thus, making them more economical than roads constructed using conventional materials
- Fly ash admixed concrete can be prepared with zero slump making it amenable for use as roller compacted concrete
- Considering all these advantages, it is extremely essential to promote the use of fly ash for construction of roads and embankments, filling of low lying areas, replacement of subgrade soil etc.
The use of fly ash in geotechnical works result in the reduction of construction cost by about 10 to 20 per cent. Typically, the cost of borrow soil varies from about Rs.100 to 200 per cubic metre. Fly ash used in this study is available free of cost at the power plant and only transportation cost of Rs. 3/-per bag has to be paid as transportation charges from Harduaganj power plant to the Department of Civil Engineering, A.M.U., Aligarh. Hence, when fly ash is used as a fill material, the economy achieved is directly related to transportation cost of fly ash. If the lead distance is less, considerable savings in construction cost can be achieved.

Similarly, the use of fly ash in pavement construction results in significant savings due to savings in cost of road aggregates. If environmental degradation costs due to use of precious top soil and aggregates from borrow areas, quarry sources and loss of fertile agricultural land due to ash deposition etc., is considered then the actual savings achieved will be much higher and fly ash use will be justified even for lead distances up to say 100 km.

Utilization of fly ash will not only minimize the disposal problem but will also help in utilizing precious land in a better way. Construction of road embankments using fly ash, involves encapsulation of fly ash in earthen core or with RCC facing panels. Since there is no seepage of rain water into the fly ash core, leaching of heavy metals is also prevented. When fly ash is used in concrete, it chemically reacts with cement and reduces any leaching effect. Even when it is used in stabilization work, a similar chemical reaction takes place which binds fly ash particles. Hence, chances of pollution due to use of fly ash in road works are negligible.

1.3 ELECTROPLATING INDUSTRY: GENERATION AND DISPOSAL OF PLATING SLUDGE

The electroplating or metal finishing industry has been playing a momentous role in the development and growth of numerous metal manufacturing and other engineering industries since the early part of this century. While electroplating operations have, in the course of time, become an essential and integral part of many engineering industries throughout the world, there has also been a steady growth of independent and small to medium scale electroplating industries, especially in the developing countries including, India. According to a report (WikiAnswers 2006), in the year
2006 about 700,000 electroplating units were working in India, out of which about 5000 units were in Aligarh, Uttar Pradesh, India. The wastewater generated in Aligarh by lock industries, specially electroplating industries is around 250 million litres per day (Agarwal 2001).

Metal plating is one of the many metal finishing processes which are basically divided as under:

- Cleaning (solvent cleaning, aqueous cleaning, abrasive cleaning, ultrasonic cleaning etc.)
- Chemical and electrochemical conversion coatings (changing or converting the surface layer to impart various properties to the surface)
- Plating (electroplating of various types of metals onto metal surfaces)
- Other metallic coating (including hot dipping and mechanical plating)
- Organic and other non-metallic coating stripping (removal of previous metallic coatings from parts or removal of coatings from articles that have to be reworked)
- Generally, metal finishing processes involve treatment of a metal work piece in order to modify its surface properties, impart a particular attribute to the surface, or produce a decoration. Plating is a subset of such finishing operations that involves putting a coating of metal over a base metal substrate to give various desirable properties to the object. Metal coating is another subset of finishing operations and involves the application of paint or powder coating to a metal work-piece. Products from metal finishing operations can range from structural steel to jewellery (Kuchar 2007).

The overall reasons to carry out a metal finishing process are summarized as follows:

- Decoration
- Protection against corrosion,
- Providing resistance to oxidation, high temperatures, or UV radiation
- Imparting mechanical properties, such as resistance to fatigue, improvement of ductile strength, or longevity
- Resistance to the use of abrasives
- Imparting electrical and thermal properties such as semi-conduction, thermal resistance, fire resistance, etc., (Kuchar 2007).
1.4 HEAVY METAL POLLUTION DUE TO ELECTROPLATING INDUSTRY

Metals having a density of more than five times than that of water may be termed as heavy metals. They are normally present in trace amounts in natural water but most of them are toxic even at very low concentrations. The problem arising from toxic metal pollution of the environment due to the increasing use of a wide variety of heavy metals in industry and in our daily life, has assumed serious dimensions.

Waste from metal finishing operations, particularly those from electroplating, are among the most toxic of industrial effluents, as they contain many different heavy metals and chemical viz., Chromium (Cr), Nickel (Ni), Cadmium (Cd), Zinc (Zn) and Cyanide (CN). Pretreatment of metal finishing wastes at the source to reduce the concentration of the toxicants below environmentally acceptable levels should be done to prepare them for discharging into streams or municipal sewage. However, a large number of industries discharge their metal containing effluents to fresh water without adequate treatment. The details of the hazardous metals present in the electroplating waste sludge are discussed below:

1.4.1 CHROMIUM

Chromium is a naturally occurring element. It is normally found in rocks, plants, soil and also in volcanic eruptions. Chromium is present in environment in different forms. The most common forms are chromium-0, chromium-III and chromium-VI. Chromium compounds contains no taste or odour. Chromium-III occurs naturally in the environment and is an essential nutrient whereas industrial processes generally produce chromium-VI and chromium-0. Chromium is present in air, water and soil mostly in the form of chromium-III and chromium-VI. In air chromium compounds are present mostly as fine dust particles, which are essential nutrient that help the body to use sugar, protein and fat. Breathing high levels of chromium-VI can cause irritation to nose. Ingesting high levels of chromium-VI compounds can cause kidney and lever damages and even death. Exposure to chromium occurs from ingesting contaminated food or drinking water or breathing contaminated work place air, living near uncontrolled hazardous waste sites containing chromium or industries that use chromium. US Environmental Protection Agency (US EPA 2006) has set a limit of
100 mg of chromium-III and chromium-VI per liter of drinking water. The US EPA (1992) has set a regulatory value of 5 ppm for the waste containing chromium for its landfill disposal.

Several studies have shown that chromium-VI compounds can increase the risk of lung cancer. The World health Organization (WHO) has determined that chromium-VI is a human carcinogen. The department of Health and Human Services (DHHS) has determined that certain chromium-VI compounds are known to cause cancer in humans.

1.4.2 CADMIUM

Cadmium is a natural element in the earth’s crust. Cadmium does not corrode easily and has many uses, including, in batteries, metal coating etc. Most important sources of atmospheric cadmium contamination are the burning of fossil fuels, municipal and medical waste and sewage sludge. Metal processing, electroplating, plastics and dye manufacturing, manufacturing and disposal of nickel-cadmium batteries, application of phosphate fertilizers are all sources of cadmium in soil and water. Cadmium enters in air from mining, industry and coal burning. It binds strongly to soil particles. Some cadmium dissolves in water. It does not break down in environment, but can change forms.

Exposure to cadmium occurs from breathing contaminated workplace air, eating and drinking contaminated food and water. Breathing high levels of cadmium severely damages the lungs and can cause death. Eating food or drinking water with very high levels severely irritates the stomach, leading to vomiting and diarrhea. Long-term exposure to lower levels of cadmium in air, food or water leads to a buildup of cadmium in the kidneys and possible kidney disease. The US EPA has set a limit of 5 parts of cadmium per billion parts of drinking water (5 ppb). US EPA does not allow cadmium in pesticides. The Food and Drug Administration (FDA) limits the amount of cadmium in food colors to 15 parts per million (15 ppm). Chronic exposure to cadmium is also associated with a wide range of other diseases, including heart disease, anemia, skeletal weakening, kidney and liver disease. High levels of cadmium in the body are associated with brittle bones. Cadmium-caused combination of brittle bones and kidney damage is called Itai-Itai (Ouch Ouch) disease. High
concentration of cadmium in the air can cause chest pain, coughing, lung problems, muscle aches, nausea, vomiting and diarrhea after 4 to 10 hours of exposure. The US EPA (1992) has set a regulatory value of 5 ppm for the waste containing cadmium for its land fill disposal.

1.4.3 LEAD

Lead is a naturally occurring bluish gray metal found in small amount in the earth crust. It comes from fossil fuels, mining etc. Lead has many uses. It is used in batteries, metal products and devices to shield X-rays. It sticks to soil particles. Lead can damage the nervous system, kidney and reproductive system. There are inadequate evidences to determine that lead is carcinogenic. The US EPA limits lead in drinking water to 1.5 mg/l. The US EPA (1992) has set a regulatory value of 5 ppm for the waste lead chromium for its land fill disposal.

1.4.4 ZINC

Zinc is one of the most common elements in the earth crust. It is found in air, soil, and water and in all foods. Pure zinc is a bluish white shiny metal. Zinc is used as a coating material to prevent rust, in dry cell batteries and mixed with other metals to make alloys like brass and bronzes. Zinc combines with other elements to form zinc compounds such as zinc chloride, zinc oxide etc. Zinc compounds are widely used in industry to make paints, wood preservatives, and ointments. Zinc is released in the environment from mining, steel production, coal burning, electroplating waste and burning of waste. Exposure to large amount of zinc can be harmful. However, zinc is an essential element for our bodies, so a small quantity of zinc is not harmful. Inadequate zinc in our diet can result in a loss of appetite, a decreased sense of taste and smell, slow wound healing and skin sores or a damaged immune system, and an excess amount of zinc can be harmful for our health. The US EPA has not classified zinc as a carcinogenic, but recommends that there be no more than 5 parts of zinc in 1 million parts of drinking water (5 ppm) because of taste. The Occupational Safety and Health Administration (OSHA) has set a maximum concentration limit for zinc chloride fumes in air at a working place as 1 mg/m$^3$ for an 8-hour work day over a 40 hour work week and 5 mg/m$^3$ for zinc oxide fumes. The US EPA (1992) has set a regulatory value of 1 ppm for the waste containing zinc for its land fill disposal.
1.4.5 NICKEL

Nickel is an abundant element that combines in the environment with oxygen and sulphur. Nickel alloys are used in the making of metal coins and jewellery and in industry for making metal items. Nickel compounds are also used for nickel-plating, to color ceramics, to make batteries. Nickel and its compounds have no characteristic taste and odor. People who are sensitive to nickel have asthma attack, skin reactions etc. Breathing large amount of nickel compounds can cause lung and nasal cancers. The US EPA (1992) has set a regulatory value of 3 ppm for the waste containing nickel for its land fill disposal.

1.4.6 CYANIDE

Cyanide is usually found combined with other chemicals to form compounds. Examples of cyanide compounds are hydrogen cyanide, sodium cyanide and potassium cyanide. It enters in the environment through natural and industrial processes.. Smoking and car exhaust are the primary sources of cyanide in the air. It can be found in water through discharges from chemical industries, iron and steel works. US EPA (2006) has set a minimum contaminant level of 0.2 mg/l of cyanide in drinking water.

1.4.7 COPPER

Copper is a naturally occurring metal, which is essential for all living things. It is used in farming to treat some plant diseases, in water treatment and to preserve wood, leather and fabrics. Copper is emitted in the air through natural processes such as wind blown dust and volcanic eruptions and human activities such as copper smelting. Copper is released in water through discharges from industries and sewage treatment plants. Long-term exposure to copper can cause irritation to nose, mouth and eyes, dizziness, headaches, and diarrhea. Copper is not carcinogenic. The US EPA has set a minimum contaminant level of copper in drinking water of 1.3 mg/l (US EPA 2006). The US EPA (1992) has set a regulatory value of 5 ppm for the waste containing copper for its land fill disposal.

Electroplating waste is a hazardous (toxic) waste and its disposal is a major issue in the industrialized world. It is done for decoration, surface protection and engineering.
performance. The electroplating of common metals includes the processes in which ferrous or non-ferrous base materials is electroplated with nickel, chromium, copper, zinc, lead, iron, cadmium, aluminum, brass, bronze or suitable combinations thereof. In this study, the fly ash and cement have been chosen for the stabilization of electroplating waste sludge. The stabilization is used as a remedial technology. The object of this technique is that the stabilized waste may be used as a material in the construction industry, especially where low grade concrete or mortar is to be required. The stabilized waste may also be used as a controlled low strength material (CLSM), which is used in backfill for utility cuts, and to fill voids under pavements, building and other structures. The stabilized waste may also be used in replacement of soil, cement, which has many applications in field operations. The safe management of hazardous wastes is of paramount importance. It is now a global concern, to find a socio and techno-economic, environmental friendly solution to sustain a cleaner and greener environment.

1.5 STABILIZATION PROCESSES

Stabilization as remedial technology for hazardous waste has been used for the last three decades, but recently it has gained momentum, due to growing number of hazardous waste generating industries. Stabilization is an established technology for the treatment of hazardous waste and hazardous waste sites. Technical reasons for the selection of stabilization as a remedial technology are that:

- It improves the handling and physical characteristics of the waste, e.g. sludges are processed into solids
- It reduces transfer of pollutants by decreasing the surface area
- It reduces pollutant solubility in the treated waste, generated by chemical changes
- Alternate hazardous waste treatment and disposal techniques are often economically prohibitive

Stabilization is a pre-landfill waste treatment process, which has been used for different types of industrial wastes, but is particularly suited to those containing heavy metals (Conner 1990; Barth et al. 1989). The solidification/ stabilization (S/S) process utilizes chemically reactive formulations that, together with the water and other components in sludges and other aqueous hazardous wastes, form stable solids. The
material used for solidification/stabilization (S/S) not only solidifies the hazardous waste by chemical means but also insolubilizes, immobilizes, encapsulates, destroys, sorbs the waste components. The results of these interactions are solids that are non-hazardous or less hazardous than the original waste. The degree of effectiveness of these S/S products is defined basically by two parameters viz., strength and the leach resistance. Methods used for studying the effectiveness of S/S process are physical, chemical and microstructural. Hills and Pollard (1997) used setting and strength development as indicators of solidification and leach test to assess the extent of fixation. S/S of wastes has been examined in the laboratory by a number of researchers. Often, pure chemical components of one contaminants of concern are added to OPC and other stabilizing agents such as ashes of different origin, lime, clay, silicates, etc., to stabilize the contaminant (Glasser 1993).

Cement contents varying from 5% to 20% are routinely used to solidify waste. Low cement content does not adequately coat individual waste particles, but still tends to provide setting and rigidity of waste. This is assumed to be the result of physical changes induced by normal “hydration process” despite the “false set” mechanism (that is, precipitation of salts such as gypsum that impart adequate strength). On the other hand, due to waste addition C-S-H hydration is poisoned. In these situations ettringite play an important role. The main product of hydration giving the early strength and stability is ettringite, which is provided primarily by the self-cementing ability of ashes. This is supported by the fact that gypsum has been previously reported by Taylor (1990) to be main binding agent in some solidified products.

Leaching tests were used in many applications, ranging from the classification of industrial wastes for disposal in landfills to assess the stability of solid wastes for their beneficial reuse. Failure to pass a leaching test requires the waste to be treated where the contaminants in the waste were immobilized by stabilization/solidification process prior to its disposal. The stabilization of waste by fly ash and cement is one the examples of such treatment. The leaching of heavy metals from cementitious waste has been investigated in many studies (Akhter et al. 1990; Hillier et al. 1999; Poon et al. 2001; Halim et al. 2003).

Fly ash, when used as structural fill material, offers several advantages over natural soil such as low unit weight, high shear strength and minimal settlement. However.
there are some disadvantages, such as dust problem, erosion due to runoff or high wind and tendency to wick water into itself. Hence, keeping in view of these problems, an endeavor is made to design and construct safe, economical fills using lime precipitated electroplating waste sludge and cement with fly ash.

The performance of the stabilized mixes depends upon the compaction or densification of the fill. Proper compaction is therefore, critical to the performance of fly ash and fly ash–waste sludge fills. The maximum dry density (MDD) and optimum moisture content (OMC) obtained by Proctor test becomes the benchmark for the determination of quality of compaction. The unit weight of fill is of primary importance since, it is the major parameter of its strength and compressibility (Clark and Coombs 1996). Significant variation in maximum dry density and optimum moisture content for different samples from the same source has been observed (Raymond 1961; Toth et al. 1988; Martin et al. 1990; Clarke and Coombs 1996). While determining the maximum dry density and optimum moisture content by standard or modified Proctor test, different methods of preparing samples for test have been reported in literature. This results in variation in the value of MDD and OMC.

Earth slopes and high vertical cuts are frequently observed to be stable for long periods in tropical and subtropical regions. Stability is often attributed to cementation effects on shear strength of fills. Foundations performance also depends on the bonded structure of the loaded fills, which contributes to reduce settlements and increase bearing capacity. Undrained shear strength parameters of fly ash was reported by Raymond (1961). Gray and Lin (1972) conducted undrained triaxial test and unconfined compression test for fly ash specimens cured up to 3-4 years. They showed through unconfined compression test results that lime stabilization enhanced the strength of stabilized fly ash at elevated temperature or with long curing period. Indraratna et al. (1991) reported the unconfined compressive strength and undrained triaxial shear tests for fly ash only. Undrained shear strength parameters of solid waste incinerator fly ash stabilized with lime and cement were reported by Poran and Ahtchi (1989).

Lime stabilization is applied in road construction to improve subbase and subgrades, for rail, roads and airports construction, for embankments, for soil exchange in unstable slopes, for backfill, for bridge abutments and retaining walls, for canal
linings, for improvement of soil beneath foundation slabs, and for lime piles (Anon 1985 and 1990). The improvement of the geotechnical properties of the fly ash and the chemical stabilization process using lime take place through two basic chemical reactions as under:

(i) **Short-term reactions:** this reaction includes cation exchange and flocculation. Where lime is a strong alkaline base which reacts chemically with fly ash causing a base exchange. Calcium ions (divalent) displace sodium, potassium, and hydrogen (monovalent) cations and change the electrical charge density around the fly ash particles. This results in an increase in the interparticle attraction causing flocculation and aggregation of the fly ash.

(ii) **Long-term reaction:** It includes pozzolanic reaction, where calcium from the lime reacts with the soluble alumina and silica from the fly ash in the presence of water to produce stable calcium silicate hydrates (C-S-H), calcium aluminate hydrates (C-A-H), and calcium aluminosilicate hydrates (C-A-S-H). This result in the long-term strength gain and improves the geotechnical properties of the fly ash (Ormsby and Kinter 1973; Choquette et al. 1987).

Properly compacted fly ash fills have exhibited adequate capacity to bear structural loads (Toth et al. 1988; Indraratna et al. 1991; Dhar et al. 1999). Low lying areas are often raised to formation level using compacted fly ash fills and structures are built on it. Bearing capacity and settlement of foundation on such fills are required input for design of foundation. However, it lacks database on the load-settlement behaviour of compacted fly ash, fly ash-waste sludge 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 are planned. Plate load tests were carried out on prepared compacted tests beds of fly ash, fly ash-waste sludge and fly ash-cement-waste sludge and their combinations. In order to examine the behaviour of these test beds under various possible conditions, tests were carried out immediately after compaction, after different periods of aging (curing) and under fully submerged conditions of test bed.
1.6 SCOPE AND OBJECTIVES OF THE PRESENT STUDY

The scope and objectives of the present investigations have been given as under:

1.6.1 SCOPE

Most of the electroplating industries produce waste sludge containing heavy metals. These heavy metals if found their way in the environment proves to be hazardous for the living and non-living things. On the other hand, fly ash which is a by-product of Thermal Power Plants has occupied a large area of agricultural land for its disposal. Hence, a proper technology has to be developed, that can utilize these potentially dangerous waste materials.

Aligarh being an only 16 km away from the Harduaganj Thermal Power Plant is subjected to pollution from fly ash that is emitted from the plant and also the fly ash is available in abundance almost free of cost. The other waste, i.e., the electroplating waste is also available on account of large numbers of hardware and lock manufacturing industries.

Most of the stabilization process of the waste sludge was carried out in the past by mixing it directly with fly ash and cement, whereas the waste sludges particularly the electroplating waste sludge contains toxic chemicals like cyanide whose prior destruction is important (Guo et al. 2001; Nathalie et al. 2006). Whereas, the precipitation of heavy metal using lime before mixing it with fly ash and cement was found to improve the performance of the mix in terms of leaching and strength.

The present study therefore, envisages the formation of a mix using fly ash, electroplating waste sludge and cement, which has potential use in geotechnical applications. The large scale use of such materials will not only help in conserving the ecological balances, but will open up opportunities for the industries to produce a low-cost material based on these waste, for mass scale applications.
1.6.2 OBJECTIVES

The aim of the present study is to carry out detailed investigations on fly ash procured from Harduaganj Thermal Power Plant and electroplating waste sludge along with cement for its subsequent utilization in various geotechnical applications. The broad objectives of the present investigations are:

(i) The detoxification of cyanide, treatment and precipitation of electroplating waste sludge obtained from electroplating plant has to be carried out.

(ii) To study the compressive strength and leaching behaviour of detoxified, treated and lime precipitated electroplating waste sludge, fly ash and cement mix. This study will set a base line for carrying out further investigations, which are important for its mass scale utilization.

(iii) To study the influence of various parameters on maximum dry density (MDD) and optimum moisture content (OMC) of fly ash and combination of fly ash-waste sludge mix.

(iv) To assess the shear strength characteristics of the mix comprising of fly ash-cement-waste sludge.

(v) To evaluate the California bearing ratio (CBR) of the mix, which is one of the most important parameters; used in the design of flexible and rigid pavements.

(vi) To study the load settlement behaviour of compacted fly ash and fly ash-waste sludge-cement fills and to suggest a procedure for estimating load-settlement values of footing on these fills.

1.7 THESIS ORGANISATION

The present work is distributed into seven chapters. The brief content of each chapter is described below:

Chapter 1 presents a brief introduction to the various aspects of stabilization of electroplating waste sludge and utilization of fly ash. The chapter also enlists the scope and objectives of the work.
Chapter 2 covers the literature review related to the problems arising due to huge production of fly ash and its utilization. The properties such as compaction, shear, bearing and settlement, which are important for geotechnical investigations are discussed. The waste generation and its impact on environment and human life have been highlighted. The stabilization and leaching of waste containing heavy metals is also presented.

Chapter 3 describes the detail procedure for treatment and precipitation of electroplating waste sludge. Experimental investigation is carried out to study the stabilization of the mix comprising of fly ash-cement-waste sludge in terms of compressive strength and leaching. Based on these studies, the optimum percentages of fly ash, waste sludge and cement are determined for carrying out further investigations related to geotechnical aspect.

Chapter 4 deals with critical examination of the procedures currently adopted for the preparation of sample for the laboratory determination of maximum dry density (MDD) and optimum moisture content (OMC) of fly ash and fly ash-waste sludge mix. Based on these studies, recommendations are made on the standard practice for compaction tests on these samples.

Chapter 5 is devoted to a detailed laboratory testing program to establish the engineering properties such as shear strength and California bearing ratio of fly ash and fly ash mixed with cement and waste sludge. The California bearing ratio tests carried out on fly ash and combinations of fly ash-waste sludge-cement mix under fresh and cured specimens, are presented and critically discussed in this chapter.

Chapter 6 deals with the load-settlement behaviour of test plate resting on compacted fly ash and fly ash-waste sludge-cement fills. The results of the plate load tests have been discussed to establish the adequacy of compacted mix as load bearing fills. The method is validated based on results of plate load tests on compacted fly ash-waste sludge-cement bed.

Chapter 7 summarizes the major conclusions and scope for further studies and presents a few recommendations which are useful in construction of fills comprising of fly ash-waste sludge-cement and design of foundations on such fills.