Thermal power station in most countries is saddled with the problem of fly ash disposal and unless suitable avenues are found for its proper use, this would pose a gigantic problem to the power sector. Disposal of huge quantities of fly ashes without proper care causes considerable impact on the environment particularly the one leading to soil and groundwater contamination. On the other hand, fly ashes have many desirable properties which can find applications in civil engineering, especially in geotechnical engineering. The pozzolanic reactivity is one of the important properties of fly ashes that enhance its application. Though the fly ashes with self–pozzolanic property are well utilized, fly ashes with insufficient free lime, such as class F fly ashes are being grossly underutilized and they form a considerable portion of fly ashes that are disposed. Yet another factor restricting the use of fly ash is the concern about the leachability of lime under field conditions particularly under saturated or partially saturated conditions. Hence an attempt is made in this thesis, to reduce the lime leachability of class F fly ashes with different additives. Thus, selection of right amounts of additives to reduce the lime leachability is an important aspect studied in this thesis. Effect of such as strength, compressibility, and CBR value is also investigated. Another simple way to reduce the problem of disposal of fly ash is to utilize it for the construction of waste disposal sites particularly for lining solid waste disposal facilities in place of the natural clay materials which are very often procured by excavating and transporting from far off places. Also, the capacities of fly ashes to sorb heavy metal that are likely to be present in the leachates generated from the industrial wastes have been studied. Of the other factors limiting the generous use of fly ashes is the leachability of several trace elements present in them. Hence the leachability of trace metals from fly ashes under different practical situations, before and after incorporating the selected additives for improving the engineering properties of fly ashes, has been studied. The thesis is presented in 10 chapters.

The relevant background for the studies and scope of the work is given
Chapter 1. Sources of the fly ashes collected for the investigating along with their physical and chemical properties are presented in Chapter 2. Two low line fly ashes are collected directly from the electronic precipitators of the thermal power plants located at Neyvelli town of the Tamil nadu and Maddanur town of Andhra Pradesh, India, named NFA and MFA respectively. MFA has greater finer particle content than NFA. The particles of MFA Have rougher surface compared to those of NFA. Both of fly ashes have predominantly quartz and mullite phase in them. The silica, total lime and carbon contents which have major influence on the pozzolanic reactivity of fly ashes vary considerably in the both the fly ashes.

Lime leachability is taken as the amount of lime that is converted into soluble form (by dissociation into calcium and hydroxyl ions) under a standardized condition. It can be used to asses the long term sustainability of the strength achieved in fly ashes with lime. Lime leachability studies have been conducted on the fly ashes stabilized with different additives in specially designed moulds. Results presented in Chapter 3 showed that leachability of lime in fly ashes increases with the increase in lime content though it is not in proportion to the increase in lime content. This is because the solubility of lime is less and is independent of the total lime present. The marginal reduction in leachability is mainly due to cemented matrix of fly ash inhibiting the leaching of time. The higher the strength of the matrix the lower is the leachability. Further it is made clear that at any lime content presence of gypsum reduces the time leachability which has been attributed to the transformation of pozzolanic compounds into less soluble form than the compounds formed with lime alone. With the increase in curing period, the amount of lime that leaches from the lime-stabilized fly ashes as well as those treated with gypsum to a considerable extent. The nature of alteration does not seem to change with time as revealed by a good correlation between lime leachability ratios obtained after 7 days and 14 days of curing periods.

Chapter 4 presents the results of unconfined compressive strength tests carried out on fly ashes with varying lime and gypsum contents, before soaking and also soaking
in several heavy metal solutions, along with the durability to the cycle of wetting and drying. The results revealed that the strength of low lime fly ashes increases with lime content significantly up to the optimum lime content of about 2.5 – 5% and gradually thereafter. Addition of gypsum of 1 – 2.5% increases the strength of fly ashes further at any lime content. Increase in strength with gypsum, which is quite significant at lower lime contents initially, is observed for a considerable period (up to 180 days) at higher lime contents. The increase in strength is as high as 40-fold in some instances. This increase in strength which is also more durable has been attributed to the formation of calcium – sodium – aluminium - silicate hydrate along with calcium silicate hydrate. Further, it is observed that fly ash which responds better to lime stabilization shows accelerated gain in strength due to the addition of gypsum at early curing periods than the fly ash that responds solely to lime. Decrease in lime leachability ratio is a good indication of the increased strength along with the increased durability.

California Bearing Radio (CBR) values are of great significance in the utilization of fly ashes in bulk quantities for the construction of road and railway embankments and pavements. Studies conducted to determine the CBR values of fly ashes with different lime and gypsum contents after curing for different time periods are described in chapter 5. The CBR values are observed to increase with lime alone significantly up to 2.5% and only marginally beyond. But the increase in CBR values is considerable with gypsum at any lime content. The increase in CBR value is particularly more with 2.5% gypsum for fly ashes with 2.5% lime. The CBR values of stabilized fly ashes are generally higher for 5 mm depth of penetration than those for 2.5 mm one due to the high stiffness of the matrix formed even at low strain levels. The loss in CBR values with soaking is relatively more at lower curing the periods due to the improper cementation of particles. Even after this significant loss in CBR values, fly ashes with 2.5% lime and 2.5% gypsum register the maximum values after curing under soaked condition. Unlike in the case of unconfined compressive strength, lime leachability values could not be well correlated with the CBR values of fly ashes with different
lime and gypsum contents since many more factors influence the CBR values than those of unconfined compressive strength alone.

Chapter 6 brings out the effects of addition of lime alone and lime along with gypsum on the compressibility behaviour of the fly ashes. Since the fly ashes when treated with additives develop strength and exhibit lower compression with the passage of time, consolidation testing with conventional duration of load increment may not be appropriate. Hence an attempt has been made to assess the minimum duration of load increment necessary to study the compressibility characteristics of such materials. Thus the compressibility behaviour of fly ashes with additives has been studied using conventional consolidation test with different durations of load increments varying from 30 minutes to 48 hours. The results indicated that 30 minutes of duration of load increment can be used to assess the compressibility behaviour of such materials. The effect of lime which reduces the compression is seen to be maximum from the results obtained with the load duration increment of 30 minutes but gradually reduce with higher duration of load increment. It has also been observed that the rate of decrease in the compressibility is maximum up to 2.5% lime and thereafter gradual. The compressibility of lime–treated fly ashes further reduces when gypsum is incorporated, the optimum gypsum percentage being 2.5. This reduction in the compressibility of fly ashes enhanced by incorporating lime and gypsum makes them versatile in the construction of embankments and for structural fills, particularly reducing the time required in between laying of each lift. It has been brought out that decrease in the lime leachability decreases the compressibility of fly ashes.

Fly ash has potential application in the construction of base liners of waste containment facilities. While most of the fly ashes improve in the strength with curing, the ranges of hydraulic conductivities they attain may often not meet the basic requirement of a liner material. Attempts to reduce the hydraulic conductivity by adding lime as gypsum along with lime to both the fly ashes are presented in chapter
Hydraulic conductivities of the compacted specimens have been determined in the laboratory using the falling head methods. It has been observed that the addition of gypsum reduces the hydraulic conductivity of the lime treated fly ashes. The reduction in the hydraulic conductivity of the fly ashes containing gypsum is significantly more of sample with high amounts of lime contents (as high as 1000 times) than those with lower amounts of lime. However, there is relatively more increases in the strengths of the samples with the inclusion of gypsum to the fly ashes even at lower lime contents. This is due to the fact that excess lime added to fly ash is not effectively converted in to pozzolanic compounds. Even the presence of gypsum is observed not to activate these reactions with excess lime. On the other hand the higher amount of lime in the presence of gypsum is observed to produce more cementitious compounds which block the pores in the fly ash. Amount of lime leached in the found to be directly related to the hydraulic conductivity inspite of many –fold variations in the hydraulic conductivity achieved by curing fly ash with lime and gypsum. The consequent reduction on the hydraulic conductivity of fly ash would be beneficial in reducing the leachability of trace elements in the fly ash when used as base liner.

Fly ash contains trace metals and other substances in the sufficient quantities which may leach out over a period of time. The study has been extended to examine the leachability of a few selected trace metals viz., Cd, Cu, Cr, Mn, Pb and Zn from fly ash before and after incorporating additives has been reported in chapter 9. The standard laboratory leaching test for the combustion residues developed by Van der Sloot et al. has been employed to study the leachabilities of trace elements as a function of liquid to solid (L/S) ratio and pH. The leachability test were conducted on the powdered fly ash samples obtained from unconfined compressive strength tests, conducted after a curing period of 28 and 180 days. It observed that, there is a marked reduction in the relative leachabilities of trace elements present, at the end of 28 days which reduced only marginally at the end of 180 days.
Chapter 9 reports the retention capacities of fly ashes for copper, lead and zinc metals ions. Various parameters like contact time, initial concentration and pH have been varied and their effect on retention mechanism studied. The retention order of metals ions, Cu$^{+2}$ > Pb$^{+2}$ > Zn$^{+2}$, is observed to be the same for both the fly ashes at all pH values. The dominant mechanisms responsible for the retention are precipitation at higher pH’s as hydroxides and adsorption at lower pH’s due to presence of silica and alumina oxide surface in fly ash. First order kinetic plots have revealed that the rate constant value increases with increase in initial concentration and pH. Langmuir adsorption isotherms have been plotted to study the maximum adsorption capacities for metal ions under different conditions. The older indicates that the adsorption is predominantly by silica surface than that by alumina or iron oxide surfaces.

This thesis demonstrates that incorporation of gypsum along with lime in the optimal proportions not only reduces the lime leachability but also greatly enhances the strength and CBR values, reduces the compressibility and minimizes the leaching of trace elements present in them enhancing the potential of fly ashes for many applications. Detailed conclusions are presented in chapter 10. The study greatly helps in promoting the use of fly ashes for many geotechnical and geo-environmental applications.