Concrete in its various forms is probably the most widely used construction material in the world. It is essentially a mixture of fine and coarse aggregate, bound together by a hardened cement paste. The use of concrete as a construction material is not a recent development, but dates back to ancient times, several thousand years ago. The ease with which concrete can be made allows anybody to mix and fabricate it, since the concrete mix will harden to a great degree even if it is not made with the right proportions or not placed properly. However, the durability of that concrete is not expected to be similar to that of properly constituted, placed or cured concrete which exhibits a long service life under most natural and industrial environments.

Concrete is an extraordinary and key structural material in the human history. Man consumes no material except water in such tremendous quantities. It is no doubt that with the development of human civilisation, concrete will continue to be a dominant construction material in the future. However, the development of modern concrete industry also introduces many environmental problems such as pollution, waste dumping, emission of dangerous gases, depletion of natural resources.

The greatest challenge before the construction industry is to serve the two pressing needs of the human society namely the protection of the environment and meeting the infrastructural requirement of our growing needs of industrialization and urbanization. The development of the construction industry in the global level needs more and more quantity of cement for construction works. But, the production of each one tonne of cement clinker releases one tonne of carbon dioxide, which affects the earth’s ecosystem. Thus, increasing production of cement worldwide is aggravating the problems associated with its production kind use. The construction industry is now slowly becoming aware of the environmental issues and other sustainable
development issues for cement and concrete industries. It is looking for the ways and means to develop building products, which will increase the life span and quality. In this regard the merits of using certain industrial by-products such as fly ash, ground granulated blast furnace slag, silica fume and metakaolin have been well recognized by the construction industry. Therefore, it should be obvious that certain scale cement replacement with industrial by-products is highly advantageous from the standpoint of cost, economy, energy efficiency, durability and overall ecological and environmental benefits. An optimum consumption of these materials without scarifying the quality of concrete to make them suitable as “Green Building” materials.

In the present investigation an attempt has been made to achieve the following objectives:

(a) to assess the mechanical and durability properties of various concrete grades (M_{30}, M_{40}, M_{50}, M_{60}, M_{70}, M_{80} and M_{90}) with the effect of partial replacement of different mineral admixtures like Fly Ash, Ground Granulated Blast Furnace Slag, Silica Fume, Metakaolin when they are mixed with superplasticizer which is a chemical admixture, on weight basis. The mineral additives used for the partial replacement of cement are Fly Ash with different percentages such as 20%, 25%, and 33%; Silica Fume with different percentages such as 10%, 13%, and 15%; Metakaolin with different percentages such as 10%, 13% and 15%; Ground Granulated Blast Furnace Slag with different percentages such as 13% and 15% and combination of Fly Ash and Silica Fume with different percentages such as (FA20+SF10), (FA20+SF13), (FA33+SF15) and combination of Fly ash and Metakaolin with different percentages such as (FA20+MK10), (FA20+MK13), (FA33+MK15) and combination of Fly ash and Ground Granulated Blast Furnace Slag with different percentages such as (FA20+BFS13), (FA33+BFS15). Normal strength, High Strength and High performance concrete grades (M_{30}, M_{40}, M_{50}, M_{60}, M_{70}, M_{80} and M_{90}) on various mechanical properties such as assessing the short term
and long term strength development by finding the compressive strength, split tensile strength values at different ages i.e., 7 days, 28 days, 90 days and 180 days and also to find the strengths of concrete cubes after conducting various durability tests like Acid Test, Alkaline Test, Sulphate Test and Rapid Chloride Permeability Test (Cylinders).

(b) to study the micro level structure configuration by generating high resolution images of the various concrete cubes prepared by the replacement of different cement samples with different types of admixtures by using Scanning Electron Microscopy (SEM) and to identify the chemical compounds formed in different combinations of cement concrete data in Energy Dispersive X-Ray Spectroscopy (EDS).

The fly ash used in the present investigation is Class F fly ash which is low in CaO and exhibits pozzolanic property. Because of its fineness as well as pozzolanic reactivity, fly ash in cement concrete significantly improves the quality of cement paste and the micro-structure of the transition zone and between the binder matrix and the aggregate. As a result of the continual process of pore refinement, due to inclusion of fly ash hydration products, a gain in the compressive strength, split tensile strength development can be identified as the age prolongs in all the concrete cubes prepared by partial replacement of cement by fly ash.

Investigation revealed that with the increase in the percentage on fly ash the resistance to acid attack is improved. Alkali Silica reaction is caused by a reaction between the hydroxyl ions in the cement pore solution in the mortar and reactive forms of silica in aggregate, which results in the formation of swelling gel of calcium silicate hydrate (C-S-H). Deleterious expansion due to CSH gel formation could be reduced or eliminated by the partial replacement of cement by fly ash in different dosages. Use of fly ash in concrete increases its resistance to sulphate attack. It is well established that the reaction of fly ash
with calcium hydroxide (CH) released during cement hydration results in the formation of additional calcium alumino-silicate hydrates and accompanying reduction in permeability. Permeability is the key to the durability of concrete exposed to harsh environments. Chloride permeability was determined in accordance with ASTM C1202 by conducting rapid chloride permeability test and results concluded that permeability is decreased with the increase in the dosage of fly ash in OPC with and without superplasticizer from moderate to low to very low.

The results of Scanning Electron Microscope (SEM) and Energy-Dispersive X-Ray Spectroscopy (EDS) study revealed that calcium, silica, aluminium are some of the major elements present and aluminium silicate (mullite) is one of the major compounds formed which is a crystalline mineral in the case of ordinary portland cement.

Ground Granulated Blast Furnace Slag (GGBS) is a glassy material which is a byproduct from blast furnaces used to make iron. The increase in the GGBS replacement reduces the pore size, increase in higher Calcium Silicate Hydrate (C-S-H) gel formation which slows down the strength increase in the early ages and increases compressive and split tensile strength as age prolongs and results in dense structure and also high durability of concrete.

Rapid chloride permeability test (RCPT) results represented highest chloride-ion penetrating resistance. The reaction products were very efficient to fill up the large capillary pores and refine the pore system in cement concrete thereby enhancing its permeability resistance. It has been observed that by increasing the slag contents in ordinary portland cement increased the sulphate resistance substantially. GGBS was very effective in controlling alkali silica reaction.

Scanning Electron Microscope (SEM) micrographs indicated that the additions of GGBS changes few needle shape ettringite existed in GGBS and
pore spaces were filled up with C-S-H gel. It is clear from EDS results that the, major elements are Calcium (Ca), Silica (Si), Aluminium (Al) which results in the formation of calcium silicate compound most of the times.

Silica fume is a by-product of the smelting process in the silicon and ferrosilicon industry. The addition of silica fume to concrete resulted in an improved bond between the hydrated cement matrix and sand in the mix, hence resulting in a significant change in the compressive strength and split tensile strength for 10%, 13% and 15% replacement with superplasticizer. The compressive strength and split tensile strength is increased in all dosages as the age prolongs this is due to the formation of C-S-H gel during the hydration of cement. Thus silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. By using silica fume along with super plasticizers it is relatively easier to obtain more compressive and split tensile strengths.

Concrete cubes prepared by partial replacement of cement by silica fume have showed much resistance to acid, alkaline and sulphate attack test 10%, 13% and 15% was observed. From RCPT test results it was clear that chloride permeability is low to very low for 10%, 13% and 15% replacement and showing much resistance in the cubes made with superplasticizer. By the addition of silica fume to concrete cubes improves the durability through reduction in the permeability, refined pore structure, leading to a reduction in the diffusion of harmful ions, reduces calcium hydroxide content which results in a higher resistance to sulphate attack.

SEM micrographs indicated that the additions of cement concrete with silica fume showed aggregation assemblages and showed flocculation bunches due to the formation C-S-H gel in ordinary portland cement with super plasticizer. It is clear from EDS results that the, major elements are Ca, Si, Al followed by potassium and aluminium which results in the formation of...
calcium potassium silicate or calcium aluminium silicate with anorthite structure most of the times.

Metakaolin (MK) is a pozzolanic material. It is a dehydroxylated form of the clay mineral kaolinite. It is obtained by calcination of kaolinitic clay at a temperature between 500°C and 800°C. Between 100°C and 200°C, clay minerals lose most of their adsorbed water. Between 500°C and 800°C kaolinite becomes calcined by losing water through dehydroxilation. The addition of Metakaolin to concrete resulted in an improved bond between the hydrated cement matrix and sand in the mix, hence resulting in a significant change in the compressive strength and split tensile strength 10%, 13% and 15% replacement with superplasticizer. The compressive strength and split tensile strength is increased in all dosages as the age prolongs this is due to the formation of C-S-H gel during the hydration of cement. Thus metakaolin has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. By using metakaolin along with super plasticizers it is relatively easier to obtain more compressive and split tensile strengths.

Concrete cubes prepared by partial replacement of cement by metakaolin have showed much resistance to acid, alkaline and sulphate attack test for 10%, 13% and 15%. From RCPT test results it was clear that chloride permeability is low to very low for 10%, 13% and 15% replacement and showing much resistance in the cubes made with superplasticizer. By the addition of metakaolin to concrete cubes improves the durability through reduction in the permeability, refined pore structure, leading to a reduction in the diffusion of harmful ions, reduces calcium hydroxide content which results in a higher resistance to sulphate attack.

SEM micrographs indicated that the additions of cement concrete with metakaolin showed aggregation assemblages and showed flocculation
bunches due to the formation C-S-H gel in ordinary portland cement with super plasticizer. It is clear from EDS results that the, major elements are Ca, Si, Al followed by potassium and aluminium which results in the formation of calcium potassium silicate or calcium aluminium silicate with anorthite structure most of the times.

The present investigation has revealed that the use of industrial by-products Like Fly Ash, Ground Granulated Blast Furnace Slag, Silica Fume and Metakaolin which are otherwise hazardous to the environment may be profitably used as a partial replacement of cement, which leads to economy and durability of the structure. Utilization of industrial by-products in this manner enhances the protection of the environment to a large extent and which eventually leads to “Sustainable Development” and growth of concrete industry.