CHAPTER 1

INTRODUCTION

1.1 GENERAL

Concrete is the most versatile man-made construction material in the world and being extensively used in all types of construction activities. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, the mix proportions, the method of compaction and other controls during placing, compaction and curing. The advances in concrete technology have paved the way to make the best use of locally available materials by proper mix proportioning and workmanship so as to produce a strong, durable and uniform concrete. One of the major thrust areas of research in concrete has been in the use of supplementary cementing materials or mineral admixtures or replacement of ingredients. The use of industrial wastes which are pozzolanic in character and develop cementitious properties are used to replace cement and aggregates partially improve strength, durability and helps to protect the environment. The environmental impacts of extracting river sand and crushed stone aggregate become a source of increasing concern in most parts of the country. Thus the production of light weight concrete with alternate aggregates is highly recommended by researchers.
1.2 LIGHT WEIGHT CONCRETE

In conventional concrete, high self weight of concrete is one of the disadvantages. Normally density of concrete is in the order of 2200 to 2600 kg/m$^3$. This heavy self weight makes an uneconomical structural material. In order to produce concrete of desired density to suit the required application, the self weight of structural and non structural members are to be reduced, thereby economy is achieved in the design of supporting structural elements which lead to the development of light weight concrete (Ramamurthy et al 2008).

Low thermal conductivity, a property which improves with decreasing density is the most important characteristic feature of light weight concrete (Ramazan Demirboga et al 2003). The reduced mass with adequate strength, improved thermal and sound insulation properties and less energy demand during construction makes lightweight concrete as well as high performance material. Though lightweight concrete can’t always substitute normal concrete for its strength potential, it has its own advantages like reduced dead load, and thus economic structures and enhanced seismic resistance, high sound absorption, high thermal insulation, and good fire resistance. (Tommy et al 2004).

Lightweight concrete is defined as a concrete that has been made lighter than the conventional concrete by changing material composition or production method.

Lightweight aggregate concrete is the concrete made by replacing the usual material aggregate by lightweight aggregates.
1.3 LIGHT WEIGHT AGGREGATES

Light weight aggregates are grouped as below.

(i) Naturally occurring materials which require further processing,

Example: Expanded clay, Shale and Slate, etc. (Serkan Subasi 2009).

(ii) Industrial by products,

Example: Sintered pulverized fuel ash (fly ash), Foamed or Expanded- blast-furnace slag.

(iii) Naturally occurring materials.


1.3.1 Aggregates Manufactured from Naturally Occurring Material

The artificial light weight aggregates are mainly made from clay, shale, slate or pulverized fuel ash. These aggregates are subjected to a process of either expansion (bloating) or agglomeration. During the process of expansion, the material is heated to fusion temperature.

When some of the material fuses (melts) and various particles are bonded together, agglomeration takes place (Mehmet Gesoglu et al 2006).

(i) Expanded or Bloated-clay

These aggregates are made from a special grade of clay suitable for expansion. The ground clay mixed with additive which encourages bloating,
is passed through a rotary or vertical shaft kiln fired by a mixture of pulverized coal and oil with temperature reaching about 1200°C. Then a material is produced which consists of hard rounded particles with a smooth dense surface texture and honeycomb interior. (Mohsen Kashi et al. 1999).

(ii) Expanded-Shale

The crushed raw materials such as colliery waste, blended with ground coal is passed over a sinter strand reaching a temperature of about, 1200°C. At this temperature, the particles expand and fuse together trapping gas and air within the structure of the material with a porous surface texture.

(iii) Expanded Slate

The crushed raw material is fed into a rotary kiln with temperature reaching 1200°C. Then a material is produced which is chemically inert and has a highly vitrified internal pore structure. This material is then crushed and graded.

(iv) Exfoliate-vermiculite

The raw material resembles mica in appearance and consists of thin flat flakes containing microscopic particles of water. When heated suddenly to a high temperature of 700-1000°C, the flakes expand (exfoliate) due to steam forcing the laminates apart. The material produced consists of accordion granules containing many minute air layers.

1.3.2 Industrial by-Products

These include sintered-pulverized fuel ash and foamed-blast-furnace slag.
(i) **Sintered-pulverized Fuel Ash**

The fly ash collected from Thermal power stations burning pulverized fuel, is mixed with water and coal slurry in screw mixers and then fed onto rotating pans, known as pelletizers. Then spherical pellets are formed. The green pellets are then fed onto a sinter strand reaching a temperature of 1400°C.

At this temperature, the fly ash particles coagulate to form hard brick-like spherical particles. Then these are screened and graded. (Rajamane et al 2004).

(ii) **Foamed-Blast-Furnace Slag**

When water or steam is introduced into molten material, a by-product of iron is produced. After annealing and cooling, a material is produced which has angular shape with a rough and irregular glassy texture. (Demirdag et al 2008).

1.3.3 **Naturally Occurring Light Weight Aggregates**

In natural state, Pumice is light and strong. Its quality varies depending upon its source. It is chemically inert and usually has a relatively high silica content of approximately 75 percent. Diatomite on the other hand is a semi consolidated sedimentary deposit formed in cold water environment.

In India, raw light-weight aggregates are produced by following methods:

(i) Bloating-clay aggregates by bloating suitable clays with or without additives,

(ii) Sintered-fly-ash aggregates by sintering the fly-ash, and

(iii) Light-weight aggregate from blast-furnace slag.
In one of the processes for manufacturing light-weight concrete, the cement and pulverized sand are first mixed in a certain proportion (1:1 for insulation and 1:2 for partitioning purposes). The mixture so formed is then made into slurry with the addition of a pre-determined quantity of water. The sand cement slurry is next foamed by using a foaming compound. The foam product is then poured into moulds. The moulded blocks are finally cured under elevated hydrothermal conditions in autoclaves by which strength is imparted and drying shrinkage is reduced. Then a creamy coloured block is formed.

In another process, the lime and sand are used as raw materials. Both are first ground to find powder in huge ball mills. Then the mixer is made into slurry with the addition of water. The aluminium powder and gypsum are added to the slurry. This causes a chemical reaction and the hydrogen gas is evolved which gives lightness to the cellular concrete. After initial hardening, it is cut into required size. Then moulded blocks are finally cured under elevated hydrothermal conditions (under a pressure of 12 atmospheres and temperature of 196°C).

The suitability of a particular light-weight aggregate is determined by the specified compressive strength and the density of concrete.

1.4 CHARACTERISTIC FEATURES OF FLY ASH

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitation. It is the most widely used pozzolanic material all over the world.
In recent time, the importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high strength and high performance concrete. Extensive research has been done all over the world on the benefits that could be accrued in the utilization of fly ash as a supplementary cementitious material.

The use of fly ash as concrete admixture not only extends technical advantages to the properties of concrete but also contributes to the environment pollution control. In India alone, we produce about 175 million tons of fly ash per year, the disposal of which has become a serious environmental problem. The effective utilization of fly ash in concrete making is, therefore, attracting serious considerations of concrete technologists and government departments. Production of every tone of cement emits carbon dioxide to the tune of about 0.87 ton. Expressing it in another way, it can be said that 7% of the world’s carbon dioxide emission is attributable to Portland cement industry. There is a need to economize the use of cement. One of the practical solutions to economise cement is to replace cement with supplementary cementitious materials like fly ash and slag.

ASTM broadly classify fly ash into two classes

Class F: Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has the pozzolanic properties only.

Class C: Fly ash normally producing by burning lignite or sub-bituminous coal. Some class C fly ash may have CaO content in excess of 10%. In addition to pozzolanic properties, class C fly ash also possesses cementitious properties.
Use of quality fly ash results in reduction of water demand for desired slump. With the reduction of unit water content, bleeding and drying shrinkage will also be reduced. Since fly ash is not highly reactive, the heat of hydration can be reduced through replacement of part of the cement with fly ash. Fly ash when used in concrete, contributes to the strength of concrete due to its pozzolanic reactivity. Since the pozzolanic reaction proceeds slowly, the initial strength of fly ash concrete tends to be lower than that of concrete without fly ash. Due to continued pozzolanic reactivity concrete develops greater strength at later age, which may exceed that of concrete without fly ash. The pozzolanic reaction also contributes in making the texture of concrete dense, resulting in decrease of water permeability and gas permeability.

The pozzolanic reactivity reduces the calcium hydroxide content, which results in reduction of passivity to the steel reinforcement and at the same time the additional secondary cementitious material formed makes the paste structure dense, and thereby gives more resistance to the corrosion of reinforcement. The addition of fly ash contributes to the reduction of the expansion due to alkali-aggregate reaction. The dilution effect of alkali and reduction of the water permeability due to dense texture may be one of the factors for reduction of alkali-aggregate reaction. Fly ash is an industrial waste, its use in concrete significantly improve the long term strength and durability and reduce heat of hydration.

1.4.1 Strength of Fly Ash Aggregate Concrete

The strength of light weight concrete depends on the density of concrete. Less porous aggregates which are heavier in weight produces stronger concrete particularly with higher cement content. The grading of concrete, water/cement ratio and the degree of compaction also affect the strength of concrete.
The properties of ingredients like cement, fly ash aggregates and the mechanical properties of fly ash aggregate concrete like compressive strength, split tensile strength and flexural strength are mainly considered in evaluating the strength.

The concrete made with bonded fly ash coarse aggregates have low density, high slump and produce minimum structural grade concrete as recommended in IS 456-2000 (Rajamane et al 2004).

1.4.2 Durability of Fly Ash Aggregate Concrete

The durability of concrete essentially dictates the permeability resistance of concrete and needs to be assessed for long time sustainability. The durability properties like sorptivity, chloride permeability, acid resistance and corrosion resistance, etc. are becoming essential to evaluate the performance characteristics of fly ash aggregate concrete. The microstructure of fly ash aggregate concrete can be studied by scanning electronic microscopy (SEM) analysis. By this analysis the adhesive and mechanical bonding of aggregate with cement paste matrix can be observed. The dense structure improves the durability characteristics. The pozzolanic reaction of fly ash involves the durability of cement paste by making the paste dense and impervious (Byung - wan Jo et al 2006).

The fly ash in optimum proportion improves the quality of concrete by lowering the heat of hydration, thermal shrinkage, increasing the water tightness, improving the chemical resistance, reducing the alkali-aggregate reaction, improving the rate of strength development, improving corrosion resistance, improving the early strength, workability and extensibility.
1.5 NEED FOR THE PRESENT STUDY

At present, 290 million tonne of coal is consumed every year which constitutes nearly 40% of total power generation which in turn produces 175 million tonne of fly ash and this is expected to increase to 225 million tonne by 2017. Serious environmental problems are caused due to this large volume of fly ash. So there is a need to develop technologies for production of value added products on sustainable basis.

The utilization of fly ash is about 30% as various engineering properties requirements that is for low technical applications such as construction of fills and embankments, backfills, pavement base and sub base course, intermediate technical applications such as in producing blended cement, concrete pipes, precast/prestressed product materials, light weight concrete bricks/blocks, autoclaved aerated concrete and light weight aggregate (Baykal and Doven 2000).

The aggregates are vital elements in concrete to improve the bulk shape of the concrete. The usage of enormous quantities of aggregates results in destruction of hills causing geological and environmental imbalance.

The environmental impacts of extracting river sand and crushed stone aggregate become a source of increasing concern in most parts of the country. Pollution hazards, noise, dust, blasting vibrations, loss of forests and spoiling of natural environment are the bad impacts caused due to extraction of aggregates. Landslides of weak and steep hill slopes are induced due to unplanned exploitation of rocks. (Behera et al 2004).

With increasing concern over the excessive exploitation of natural aggregates and environmental pollution, there is a need to look for an alternative aggregate which is economically viable and suitable for the
construction industry. Fly ash aggregate is a viable new source of structural aggregate material. Usage of fly ash aggregate in concrete is the best disposal route of fly ash and also solves the problem of environmental pollution.

In view of the above, an attempt has been made in the present work to develop a concrete with complete replacement of fine and coarse aggregates by fly ash aggregates. This fulfils the need of alternative aggregates in concrete and prevent the environmental pollution due to the disposal of fly ash.

1.6 OBJECTIVES OF PRESENT STUDY

An attempt has been made in the present work to develop a concrete using fly ash aggregates and to assess its strength and durability characteristics.

The following are the set objectives in the present work.

(i) To evaluate the properties of fly ash aggregates and concrete.

(ii) To study the strength characteristics of fly ash aggregate concrete.

(iii) To study the durability performance of fly ash aggregate concrete.

(iv) To evaluate the performance characteristics of fly ash aggregate concrete by developing the relationships between strength and durability.

(v) To investigate the microstructure of fly ash aggregate concrete.

(vi) To study the economy of fly ash aggregate concrete.
1.7 ORGANISATION OF THE CHAPTERS

The present work on strength and durability aspects of fly ash aggregate concrete is organized in five chapters.

**Chapter 1** provides an introduction to light weight concrete, various natural and artificial light weight aggregates. The characteristics of fly ash, strength and durability of fly ash aggregate concrete have been presented.

**Chapter 2** deals with critical review of literature on property of light weight concrete, light weight aggregates, strength and durability of fly ash aggregate concrete and mix proportioning of light weight concrete.

**Chapter 3** presents the material and methodology adopted in the present work. It includes methodology adopted to study the strength and durability characteristics of fly ash aggregate concrete.

**Chapter 4** presents the results and detailed discussion related to strength, durability characteristics and microstructure of fly ash aggregate concrete. The performance characteristics of strength and durability of fly ash aggregate concrete have been presented. The cost aspects of fly ash aggregate concrete are also presented.

**Chapter 5** presents the conclusion of the experimental investigation along with suggestions for further research work.