1.0 INTRODUCTION

1.1 GENERAL

Developing countries like India, industrialization was a must and this is very much important to build a self reliant and in uplifting nation’s economy. However, urbanization growth rate in India is very high due to industrialization and also caused serious problems relating to environmental pollution. Rapid infrastructure development requires a large quantity of construction materials, land requirements and the site. With increasing demand for construction materials like coarse aggregates, sand and cement, the non-traditional sources such as byproducts from construction and demolition waste (C&DW) and industry etc is thought of. Therefore, efforts are to be made for conversion of unwanted C&DW and industrial wastes into utilisable raw materials for various beneficial uses and there by controlling material demand and environmental pollution arising out from the disposal of wastes.

1.2 RECYCLING OF CONSTRUCTION AND DEMOLITION WASTE

Concrete has been proved to be a leading construction material for more than a century. The large amount of depletion of natural aggregate (NA) and the increased amounts of wastes from construction and demolition going to landfill sites are causing serious problems to handling and safe disposal without causing significant damage to the environment. It is estimated that the global production of concrete is at an annual rate of 1 m³ per capita. As per the research by Fredonia group, World construction aggregates demand is forecast to 28 billion metric tonnes by the year 2013. India is also one among the top ten users of construction materials. Over 1 billion tonnes of C&DW is generated every year worldwide. From environmental point of view, for production of natural
aggregates of 1 ton, emissions of 0.0046 million ton of carbon exist whereas for 1 ton recycled aggregate (RA) produced only 0.0024 million ton carbon is produced. Considering the global consumption of 10 - 12 billion tons/year of aggregate for concrete production (Tsung et al. 2006), the carbon footprint can be determined for the NA as well as for the RA.

The use of the RA created from processing C&DW in new construction has become more important over the last two decades. There are many factors contributing to this, from the availability of new material and the damage caused by the quarrying of NA and the increased disposal costs of waste materials. Recently, these aggregates started to be used for intermediate utility applications such as foundations for building and roads. However, more care is to be taken on physical and chemical characteristics of the RA and hence it can be used to produce recycled aggregate concrete (RAC) by minimizing environmental problems and optimizing the cost without compromising the quality.

The advantages of recycling C&DW are as follows: It reduces the amount of construction and demolition waste entering landfill sites, reduces the use of natural resources in construction, contributes to the environment, provides a renewable source of construction material and used in situ, reduces haulage costs.

1.3 RECYCLING OF INDUSTRIAL WASTES

Industrial wastes like fly ash (FA) and ground granulated blast furnace slag (GGBFS) are also available in abundant quantity and create lot of disposal problem. Formation of landfills in thermal industries is an inevitable problem. To solve the above issues, these waste materials can be used as partial replacer to cement in construction industry. However, the use of FA and GGBFS in construction is nothing new and has a long history of use in
concrete. The reduction of Ordinary Portland cement production will reduce carbon dioxide (CO₂) emissions, reduce energy consumption and reduce the rate of global warming. One ton of cement production causes one ton of CO₂ emission and India is now the second largest cement producer in the world after China, with around 300 million tonnes of cement production capacity. Utilization of FA and GGBFS usually provides cost savings as well as improved concrete properties. The advantages offered by the use of admixtures in modern concrete are, it is considered very beneficial, from different prospects with similar performance characteristics to natural aggregate concrete (NAC).

The use of FA is accepted in recent years primarily due to saving cement, consuming industrial waste and making durable materials, especially due to the improvement in the quality stabilization of FA. Fly ash is another type of pozzolanic material widely being used as a cement replacement. Many researchers indicated that low-calcium fly ash (Class-F) improves the interfacial zone microstructures. Portland cement hydrates to produce calcium hydroxide as much as 20% to 25% by weight. This compound, besides other alkali oxides like Na₂O and K₂O generates alkalinity. When the pozzolanic materials in the form of FA are added to the cements, the CH of hydrated cement is consumed by the reactive SiO₂ portion of these pozzolanas. This pozzolanic reaction improves microstructure of cement composites as additional C-S-H gel is formed and also the pore size refinement of the hydrated cement occurs. Hydration of tri-calcium-aluminate in the ash provides one of the primary cementitious products in many ashes. The rapid rate at which hydration of the tri-calcium-aluminate results in the rapid set of these materials and is the reason why delay in compaction result in lower strengths of the stabilized material.
In a similar passion, the use of GGBFS is also accepted among researchers primarily due to saving cement, consuming industrial waste and making durable materials. The principal hydration product that is formed when GGBFS is mixed with Portland cement and water is essentially the same as the principal product formed when Portland cement hydrates, i.e., calcium-silicate-hydrates (C-S-H). GGBFS hydrates are generally found to be more gel like than the products of hydration of Portland cement, and so add denseness to the cement paste. When GGBFS is mixed with water, initial hydration is much slower than Portland cement mixed with water; therefore, Portland cement or alkali salts or lime are used to increase the reaction rate. Hydration of GGBFS in the presence of Portland cement depends largely upon breakdown and dissolution of the glassy slag structure by hydroxyl ions released during the hydration of the Portland cement. In the hydration of GGBFS, the GGBFS reacts with alkali and calcium hydroxide (Ca (OH)_2) to produce additional CSH (ACI 233R-95).

1.4 NEED FOR MORE RESEARCH ON MINERAL ADMIXED RAC

In India, the Central Pollution Board (CPCB) has estimated the solid waste generation as about 48 million tonnes per annum of which 25% are from construction industry. This creates significant problems on solid waste management. The major contribution to waste generation is from the demolition of buildings. The total amount of waste is estimated to be 12 to 14.7 million tonnes per annum from the construction industry, out of which only 3% waste is used for embankment. Projections of building material requirement of the housing sector indicate a shortage of aggregates to the extent of about 55,000 million cubic meters. Recycling of aggregate material from C&DW may reduce the demand–
supply gap in both these sectors. The waste from concrete and masonry is more than 50% of the total construction and demolition waste and is not currently recycled in India.

As per the report submitted by TIFAC (Technology, Information, Forecasting and Assessment Council) regarding the possibility of recycling of C&DW from construction industry (www.tifac.com), the most dominant reason for not adopting the recycling of waste from construction industry is “lack of awareness of the recycling techniques”. Around 70% of the respondents have cited lack of awareness as one of the reason, 30% of the respondents have indicated that they are not even aware of recycling possibilities. The recycled product industries responded that, presently the specifications do not permit the use of recycled product in the construction activity. Around 67% of the users responded that the non availability of recycled product as one of the reasons for not using it.

European standardization has made it far easier to specify RA. Also many application issues have been resolved and satisfactory use has been demonstrated in a variety of concretes. Still the use of RA in concrete is relatively rare. There are three main reasons for that [Lay 2009]:

1. Overall economics – direct costs can also be unfavorable
2. Chicken-and-egg situation of steady supply of suitable aggregates – aggregate producers do not want to build up large stock of RA for concrete since there is no market and concrete producers cannot plan to make RAC without the security of large supplies.
3. Other end users are far more tolerant than concrete of the inevitable contaminants in RA.
Technical problems may include:

- high content of cement paste/mortar in RA
- weak interfacial transition zones between cement paste and aggregate
- porosity and traverse cracks within demolished concrete
- high level of sulphate and chlorides
- impurity
- poor grading
- high variation in quality [Tam et al. 2007]

In view of the aforesaid figures and discussion, it can be predicted that there will be a large reserve of C&DW worldwide and therefore considerable amounts of RA are going to be available in the near future. The assessment of the above problem demonstrated that C&DW and post-industrial wastes, particularly FA and GGBFS, are the most abundant materials readily available as potential substitutes for cement, fine aggregate, and NA. Both are produced in large amounts in many places around the world, and frequently end up in landfill sites presenting a challenging environmental problem. In view of these findings, the need for more research work is obvious to match society’s requirements for economic and safe disposal of wastes. However, all parties such as policy makers, planners, developers, designers, contractors, and suppliers need to be involved and should play a part to make the practical use of these research findings possible. The effective use of these wastes is considered a key component of global construction ecology.
1.5 ORGANIZATION OF THESIS

This doctoral thesis deals with the strength and durability characteristics of RAC with admixtures. This thesis consists of six chapters. Brief descriptions of the chapters are given below.

Chapter 1 is an introductory chapter that gives the brief background about this thesis to the reader.

Chapter 2 summaries the related research work on RAC, concrete with mineral admixtures like FA and GGBFS and the objective of this research work.

Chapter 3 describes the material properties used for concrete preparation and explains the methodology adopted for this study. Mix design and the testing procedure of the various tests conducted are also elaborated.

Chapter 4 presents the results and detailed discussion on various experimental investigation of the use of RA as the replacement of NA and high volume fly ash (HVFA) and GGBFS as the replacement of cement in concrete. The detailed discussion includes the characteristics of strength, durability, micro structure analysis, regression model, cost analysis and structural behaviour of RAC with HVFA and GGBFS.

Chapter 5 summarize the conclusions obtained from the experimental work and discusses scope for future research work about the mineral admixed RAC as a continuation of this work.