CHAPTER-1
INTRODUCTION
1.1 PRELUDE

Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise buildings, defense installations, environment protection and local/domestic developments. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixture(s). Among these, aggregates, i.e. inert granular materials such as sand, crushed stone or gravel form the major part. Traditionally aggregates have been readily available at economical prices and of qualities to suit all purposes. However, in recent years the wisdom of our continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection. In light of this, the availability of natural resources to future generations has also been realized (D N Parekh & Dr C D Modhera, 2011).

The concrete construction industry is not sustainable due to one or other reason. First, it consumes huge quantities of virgin materials. Second, the principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions that are implicated in global warming and climate change. Third, many concrete structures suffer from lack of durability which has an adverse effect on the resource productivity of the industry. Use of industry waste like fly ash, silica fume, grounded furnace slag to partly replace cementing material, concrete system addresses all three sustainability issues, its adoption will enable the concrete construction industry to become more sustainable.

Recent research by the Fredonia group has established that the global demand for construction aggregates may exceed 26 billion tones by 2011. Leading this demand are the single user: China (25%), EU (12%) and the USA (10%). However, because of industrialization and significant infrastructure and construction development, there are expected to be a significant increase in use of aggregates in India (which is already one of the major national markets at 3%) beyond 2011. In India, about 14.5 MT of solid wastes are generated annually from construction industries, which include wasted sand, gravel, bitumen, bricks, and masonry, concrete. However, some quantity of such waste is being recycled and utilized in building materials and share of recycled materials varies from 25% in old buildings to as high as 75% in new buildings. Hence the subject of concrete recycling is regarded as very important in the general attempt for sustainable development.
in our times. In a parallel manner, it is directly connected with (a) increase of demolition structures past out of performance time, (b) demand for new structures and (c) results of destruction by natural phenomena (earthquakes, tsunami etc.). (D N Parekh & Dr C D Modhera, 2011).

Concrete is the most widely used construction material all over the world. In view of its strength, high mouldability, structural stability and economic consideration, concrete has a good future. On account of its ease to produce infinite variability, uniformity, durability and economy, concrete cannot be replaced by any other material.

The race of human history has surpassed all its inventions after the discovery of cement and research in concrete. The gray colored powder and its mixture have witnessed the all human struggle and success in winning over landscape, sacred rivers and stubborn mountains and oceans. The bridges and dams over rivers and Jetties on shore of the oceans are power packed victory over nature. Sky scrapers are of perfect significance of many titanic jumps. Concrete has played a key role in the development of our planet ‘earth’ in developed, developing and under developed countries. The historic material ‘cement’ and its end product ‘concrete’ is nearly 9000 years old. It has undergone several changes not only in composition, but also in its performance and applications. From simply beginning around 700 B.C. to more complicated designs and application in twenty first century. History of cementing material is as old as history of engineering construction. Some kind of cementing materials was used by Egyptians, Romans and Indians in their ancient construction. Earlier Egyptians mostly used cementing material obtained by burning Gypsum. The Romans used a mixture of volcanic ash and calcined lime. While Indians used surkhi (Burn clay powder and calcined Lime)

Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. The aim for this project is to determine the strength characteristic of recycled aggregates, for application in structural concrete, which will give a better understanding on the properties of concrete with recycled coarse aggregate, as an alternative material to coarse aggregate in structural concrete. The scope of this project is to determine and compare the strength of concrete by using different percentage of recycled aggregates.
1.2 Aggregates

The aggregate in concrete has three main functions:

1) To provide a relatively cheap filler for the cementing material.

2) To provide a mass of particles which are suitable for resisting the action of applied loads, abrasion the percolation of moisture and the action of the weather.

3) To reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement paste.

Aggregate comprise 70 to 80% of the volume of concrete and exert a significant influence on concrete properties. Generally, they are granular material derived from natural rock or natural sands and gravels. However, one of the fact that has made concrete, the world’s most widely used construction material is its ability to absorb a wide range of quality of materials, including recycled and industrial by products, as a component of the aggregate (and cement). In selecting aggregate for use in concrete certain constituents should be avoided. For example, reactive silica leads to deterioration of concrete if moisture and alkali are present; weak friable aggregate should not be used if hardness is desired concrete property; and a highly porous aggregate is potentially unsuitable with respect to aggressive permeation – based deterioration processes (e.g. chloride ingress and carbonation). Some of these properties are directly dependent upon the parent rock whilst others are not. For example, those dependent on parent rock are chemical and mineralogical descriptions, petrographic description, specific gravity, strength, hardness, and color, whilst, surface texture, size and shape are independent of parent rock.

The simplest and most common method for characterization of aggregate is on the basis of the specific gravity, i.e. (i) normal weight (ii) light weight and (iii) heavy weight. Further characterization may be achieved using the following: grading, shape, inclusion, bulk density, water absorption, chemical composition and drying shrinkage (D N Parekh & Dr C D Modhera, 2011).

1.3 Recycled Aggregates

Use of recycled aggregate in concrete can be useful for environmental protection and economical terms. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in many construction projects in many European, American and Asian countries. Many countries are giving many infrastructural laws relaxation to increase the use of recycled aggregate.
Concrete is the world’s second most consumed material after water, and its widespread use is the basis for urban development. It is estimated that 25 billion tonnes of concrete are manufactured each year. Twice as much concrete is used in construction around the world when compared to the total of all other building materials combined. Many countries have recycling schemes for C&DW to avoid dumping to landfill, as suitable landfill sites are becoming scarce particularly in heavily populated countries. Charges or levies on landfill dumping often make recycling concrete aggregate a preferred option.

The reuse of hardened concrete as aggregate is a proven technology - it can be crushed and reused as a partial replacement for natural aggregate in new concrete construction. The hardened concrete can be sourced either from the demolition of concrete structures at the end of their life – recycled concrete aggregate, or from leftover fresh concrete which is purposefully left to harden – leftover concrete aggregate. Alternatively fresh concrete which is leftover or surplus to site requirements can be recovered by separating out the wet fines fraction and the coarse aggregate for reuse in concrete manufacture recovered concrete aggregate. Additionally, waste materials from other industries such as crushed glass can be used as secondary aggregates in concrete. All these processes avoid dumping to landfill whilst conserving natural aggregate resources, and are a better environmental option.

Significant quantities of waste are being produced and discarded by the construction and demolition (C & D) industries within the Asia and many other developed countries, and this is likely to increase considerably in the future. On the other hand, in recent years the construction industry throughout the world has supported initiatives to improve sustainability by increasing the use of recycled aggregates in concrete production. This is mainly because of the depletion of quality primary aggregates and in some quarters, greater awareness of environmental protection (D N Parekh & Dr C D Modhera, 2011).

The subject of concrete recycling is regarded as very important in the general attempt for sustainable development in our times. In a parallel manner, it is directly connected with (a) increase of demolition structures past out of performance time, (b) demand for new structures and (c) results of destruction by natural phenomena (earthquakes, tsunami etc.). Construction & Demolition (C&D) wastes are normally composed of concrete rubble, bricks and tiles, sand and dust, timber, plastics, cardboard and paper, and metals. Concrete rubble usually constitutes the largest proportion of C&D waste. It has been shown that crushed concrete rubble, after separation from other C&D waste and sieved,
can be used as a substitute for natural coarse aggregates in concrete or as a sub-base or a base layer in pavements. This type of recycled material is called **recycled aggregate** (D N Parekh & Dr C D Modhera, 2011).

Recycled aggregates are those resulting from the processing of materials previously used in construction. Recycled aggregates can be broadly subdivided into two main categories: RA derived predominantly from crushed concrete rubbles and RA created from the rather broad field of C&DW such as brick-based RA and asphalt-based RA. The level of impurities in the second category (particularly those derived from asphalt pavements) is usually medium to high and can significantly affect the strength and performance when recycled in concrete; therefore aggregates in this category are often used for secondary applications and are of little interest for use in concrete. Another barrier facing the use of this category in concrete are the limitation and provisions set in standards such as BS 8500-2: 2002. In this standard, restrictions were put on the maximum masonry content, fines content, asphalt, acid-soluble sulphate, and other contaminant material such as glass, plastics, and metals. In addition, rejection by the public and the concrete industry, particularly in places where there is a good reserve of proven natural aggregate has been a barrier. With these restrictions, it is most unlikely that concrete suppliers would be able to accept this type of RA for concrete mixes.

Globally the concrete construction industry has taken a responsible attitude to ensuring its natural resources are not overexploited. In some cases the preservation of dwindling natural aggregate sources is a significant issue driving the use of recycled aggregates. Reduction in the impact of aggregate cartage on cost and environmental issues is also a factor where material processed from the demolition phase of a project, using a portable aggregate processing plant, can be reused in concrete for the construction phase of the project. This is a better option than transporting natural aggregates from quarries which through urbanisation are located at an ever increasing distance from city areas. In some cases in India and some countries, for instance, quarried aggregate is transported over 100 km from source to construction projects.

In the general awareness of concrete recycling as an issue in India is not high. However, overseas, landfill levies, waste dumping taxes and imported aggregate taxes have made it viable to recycle concrete generally into a ‘low-grade’ road-base material. The greatest users of recycled aggregate in new concrete are the United Kingdom, Netherlands, Belgium, Switzerland and Germany. In these countries recycling rates are
higher as a result of a longer period of awareness of concrete recycling, and the preservation of dwindling aggregate resources. Other countries are likely to follow this trend with time.

The key to local materials recovery and the recycling industry sector is to achieve a balance between economic pressures and ecologically sound practices. This balance is critical not only to ensure a sustainable future for the industry, but also to secure essential quality improvements and development of markets for value-added products, which are required to make recycled materials more attractive and economical. Several market constraints and technical challenges exist when developing markets for secondary products. Notable among these barriers is consumer uncertainty about the quality and consistency of products. In addition, there can be a lack of practical performance and engineering data on recycled materials. Such data are necessary to assist with the development of appropriate design codes to guide product specification and performance information on recycled materials (CCANZ, 2011).

1.4 Sustainability in the Concrete Industry

Recycling concrete is not an end in itself. A full Life Cycle Assessment of the concrete structure, including the recycling phase at the end of its life, is required to assess the overall sustainable credentials of the structure. It is useful to place concrete in the context of the environmental impact of other construction materials. As regards the concrete manufacturing phase, much effort has gone into reducing the environmental footprint of cement manufacture. Cement manufacture is the target area for carbon emissions reduction efforts as it is this stage of production where the most greenhouse gas impact occurs. (WBCSD, Geneva, Switzerland). Transportation and delivery at all stages of concrete production is the second greatest source of impact. Any savings in transport by using recycled aggregate as compared to using natural aggregate reduce both the cost and the environmental burden. Also recycling concrete into aggregate tends to produce environmental benefits by preserving natural aggregate, a finite resource.
1.4.1 Advantages of Recycling C&DW

The advantages of recycling C&DW are numerous:
1) Reduces the amount of C&DW entering landfill sites.
2) Reduces the use of natural resources in construction.
3) Contributes to the environment.
4) Provides a renewable source of construction material.
5) If used in situ, reduces haulage costs.

1.4.2 Current Knowledge base on the use of Recycled Aggregates in Concrete

Regarding that the quality data of old concrete is often unknown (w/c ratio, kind and amount of admixtures, aggregates origin and gradation, etc.), as well as the differentiation of its properties during its performance time, the knowledge and tests of RCA should refer to four categories:

a) Historical data of RCA referring to the composition of old concrete, masonry etc. petrography characteristics, data of old structures.
b) Physical characteristics, especially in water absorption, specific gravity, amount of chlorides and sulphates, amount of contained foreign ingredients, possibility of creation of alkali–silica reaction.

c) Mechanical characteristics.

d) Environmental characteristics.

There were a number of seminar works on the use of recycled aggregate in concrete prior to 1996, it was from 1996 until 2002 that the main knowledge base on use of recycled concrete aggregate (RCA) was formed since at that time these materials reflected the highest and most consistent quality of all recycled aggregates available. Mobile crushers whilst often more economical in that they avoid transporting C&D waste away from site, are rarely sophisticated enough to remove all impurities. Therefore, recycled aggregates produced from mobile crushers are usually used as fill or capping layers, and used at, or close to the location that they were crushed. In contrast, recycled aggregates from central recycling facilities undergo a number of processes to ensure higher quality. This may include: magnets, picking stations, (although these are becoming rare), trash screen, screens, log washers, water pumps and sludge tanks. Furthermore, central recycling facilities take great care to control the type of C&D waste that is allowed to be stockpiled. Impact crushers are beneficial as they give RA a more rounded shape which aids engineering performances.

Soil, silt and clay can be particular problems and care is usually taken to avoid these materials entering the C&D waste stream at the source. On site, contractors use a scalping screen ahead of the primary crusher to remove soil and clay balls; whilst washing plants, are able to rely on the soil and clay being removed during washing processes. Furthermore, innovative methods, for example the creation of filter cakes for use in drainage are used to avoid the resulting soil, silt and clay being directed to landfill.

In Japan, there have been attempts to further improve the quality of recycled aggregate via, for example the methods briefly stated below:

1. Heating and Rubbing: whereby the recycled aggregates are heated to 300°C to remove weaker mortar and cement particles from the aggregate.

2. Eccentric – Shaft Rotor Method: in which the recycled aggregates are passed between two cylinders eccentrically rotating at high speed which separates coarse aggregates from mortar via a grinding effect, and

3. Straight Forward Mechanical Grinding: In which aggregates are placed in a rotating drum containing iron balls.
Only a few cases have been reported on the use of recycled aggregates in structural concrete, and the amount of recycled aggregate used has generally been limited to a low level of replacement of the total weight of coarse aggregate. An example is a viaduct and a marine lock project in the Netherlands in 1988, and an office building in the UK in 1999. In the first case, a total of 11 000 m³ of concrete in which 20% of the coarse aggregates were replaced by recycled aggregates were used in all parts of the structures. Another reported case involved the use of 4000 m³ of ready mixed concrete, which was prepared with recycled aggregates obtained from crushed concrete railway sleepers to replace 40% of the coarse aggregates. The limited use of recycled aggregate in structural concrete is due to the inherent deficiency of this type of material. In comparison with natural, normal weight aggregates, recycled aggregates are weaker, more porous and have higher values of water absorption. The results of research studies show that when recycled aggregates obtained from crushed concrete are used to replace up to 20% by weight of the coarse natural aggregate in concrete, little effect on the properties of concrete is noticed (D N Parekh & Dr C D Modhera, 2011).

1.4.3 Economics and Best Practicable Options for Recycled Coarse Aggregates

The main alternative to using recycled aggregates is, of course, natural aggregate and these are still relatively low cost materials. However, in a purely economic balance, the cost of processing of recycled aggregates in the UK is becoming less than that of disposing of the demolition waste and purchasing new aggregates, due to increases in landfill tax and the newly introduced aggregates levy. If recycled aggregates have to be transported a significant distance from the place of production to the place of use, then both the cost and environmental benefits may become more questionable.

It is now widely accepted that there is a significant potential for reclaiming and recycling demolished debris for use in value added applications to maximize economic and environmental benefits. As a direct result of this, recycling industries in many parts of the world, including South Africa, at present converts low-value waste into secondary construction materials such as a variety of aggregate grades, road materials and aggregate fines (dust).

In India, the cost of construction materials is increasing incrementally. As a result, in India, the informal sector and secondary industries recycle 15–20% of solid wastes in various building components. (D N Parekh & Dr C D Modhera, 2011)
Figure 1.2 Turning C&DW to Recycled Aggregates of Different Sizes
(Source: Google)

Figure 1.3 Schematic flow diagram of small scale Concrete Recycling Plant
(Source: Google)
1.4.4 Utilization of Recycled Coarse Aggregate in concrete

Recycling of concrete is needed from the viewpoint of environmental preservation and effective utilization of resources. At present, utilization of recycled aggregate is limited mainly to sub bases of roads and backfill works. A large portion of concrete waste ends up at disposal sites. It is anticipated that there will be an increase in the amount of concrete waste, a shortage of disposal sites, and depletion of natural resources especially. This leads to the use of recycled aggregate in new concrete production, which is deemed to be a more effective utilization of concrete waste. However, information on concrete using recycled aggregate is still insufficient, and it will be advisable to get more detailed information about the characteristics of concrete using recycled aggregate.

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced
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development in the infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate is comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

1.5 RESEARCH OUTLINE

The thesis report is organized in seven chapters as outline here with references and adding appendices at the end.

Chapter 2 deals with detailed literature review on using Recycled Coarse Aggregate in concrete.

Chapter 3 describes the objectives and research plan with concrete mix design.

Chapter 4 deals with a description of the materials used in the experiment and also a brief explanation about the procedure of the experimentations.

Chapter 5 deals with the study of characteristic properties of Recycled Coarse Aggregate with varying percentage, and hence to arrive at an optimum percentage of high strength and high performance concrete to be used.

Chapter 6 describes the mathematical models are developed using regression analysis of the strength characteristic of concrete when subjected to different Percentage replacement of Natural Coarse Aggregate by Recycled Coarse Aggregate.

Chapter 7 deals with major findings, conclusions and future scope.