Chapter 1

Introduction

1.1 Background

The construction industry contributes substantially to the generation of solid waste in almost all the countries. In North America the construction and demolition waste contributes around 25 – 40% of the total waste generated depending upon the region (Tabsh and Abdelfatah 2009). The Construction Materials Recycling Association (CMRA) has conducted a study on construction and demolition waste, related to the buildings and it was estimated to be around 136 million tonnes of waste material. Also, it was reported that apart from the building waste, a millions of tonnes of waste is coming from road, bridge, and airport construction and renovation. In developed countries the annual per capita building and construction waste generation were 500 – 1000 kg and in the European countries the building and construction waste was estimated to be around 175 million tonnes per year (Nitivattananon and Borongan 2007). The construction and demolition waste generation scenario in Asian countries is also in the same trend. It was reported that Asia alone generates about 760 million tonnes of construction and demolition waste every year (World Bank 1999). According to the annual report of Dubai municipality's Waste Management Department, there was about 27.7 million tonnes of construction waste, generated from various construction sites in the city in 2007 (Shrivastava and Chini 2009). This was recording growth in construction waste generation of 163% in comparison to the waste generated in 2006.

Like other developing countries, India too is generating a huge quantity of construction and demolition waste due to rapid growth in construction industry. According to 11^{th} five year plan the construction industry is second to agriculture in terms of magnitude (Government of India 2007). It is one of the largest employers in the country. The employment figures have shown steady increase from 14.6 million in 1995 to 31.46 million in 2005. The construction industry in India significantly affects the economic growth of the country. During 2004 – 2005, over US$ 100 billion has been invested in this sector. Due to the Government of India's (GOI) recent initiative to allow 100% foreign direct investment in real estate development projects, the construction sector likely to continue to record higher growth in the coming years (Market Research 2006). The contribution of the construction industry in total gross domestic product (GDP) has risen from 6.4% in 2000 – 2001 to 7.2% in 2004 – 2005 (TIFAC Ed 2005). Technology Information, Forecasting and Assessment Council (TIFAC) indicate that the total construction work is equivalent to $847 billion during the period 2006 – 2011 (TIFAC Ed 2005). According to the tenth five year plans the materials cost was around 40 – 60% of the total project cost. The construction and demolition waste in India was estimated to be approximately 14.5 million tonnes per year (Pappu *et al*. 2007). The Central Pollution Control Board (CPCB) had estimated the total solid waste generation as 48 million tonnes per year for the year 2001 and out of which 12 – 14.7 million tonnes from the construction industry alone and by 2010, this was expected to be around 24 million tonnes (TIFAC Ed 2005). In addition, the new zoning bye-laws, legitimization of squatter settlements and increase in the urban population due to industrial development have led to the demolition of structures in the larger cities. Insufficient capacity of old road bridges for present and future growing traffic and modernization of highway bridges needs the demolition of old bridges too. Also, structures are destroyed due to either natural disasters like earthquakes, cyclones etc. or man-made disasters. Hence, the entire world is facing the problem of handling the waste material generated from the demolition. On the other side, there is a huge requirement of raw materials in the construction sector in India. Projections for building material requirement of the housing sector indicate a shortage of aggregates to the extent of about 55,000 million cubic meters. For achieving the target for road development up to 2010, an estimated 750 million cubic meters of coarse aggregate as sub-base material shall be required (TIFAC Ed 2005). Recycling of aggregate material from the construction and demolition waste may reduce the demand-supply gap in both these sectors.

The use of old construction materials in new constructions is not a new technique. Many civilizations have used and reused the construction materials of earlier civilizations or their own destroyed architectures either due to war or due to natural disaster to construct new structures. The best example is that the construction of Vatican Basilica with the stones of ruined Romanesque. Though the '3R' formula i.e. Reduce, Reuse, Recycle is one of the best policies to achieve the sustainable construction, due to partial implementation of this technique in most of the countries still lots of quantities of construction and demolition waste is lying in the site and deposited on landfills. The

European Demolition Association estimates that about 200 million tonnes of waste generated annually, out of which 30% of this quantity being recycled. However, there was large difference in the quantities of recycling in the region wise. For example, Netherlands and Belgium achieve recycling rates of about 90%, whereas, other European countries like Italy and Spain, the recycling rate was below 10% (Collepardi 2002). The Japan and Germany have also reached the recycling rates of around 96% and 86% respectively. The CMRA estimate that 25% of the construction and demolition waste was recycled and most of these recycled materials were used as base materials for road construction. In India, the construction and demolition waste is not being recycled currently.

Although there is a considerable potential for using the construction and demolition waste as aggregates in concrete, considerable amount are either remain in site or land filled, the "last resort" in the waste management hierarchy (Rao 2005). Most of the developed/developing countries, the construction waste treated as inert waste, harmless and bulky, which does not give rise to problems. However, this waste consists of mixture of various materials of different characteristics that are often deposited (dumped on land) without any considerations, causing many problems and encouraging the illegal dumping of other kinds of waste. This puts an additional burden to the solid waste management. Also, there is a shortage of dumping sites in the developed countries. Further, there is increase in the cost of transport to dispose waste to the dumping sites. Additionally, there is a need to preserve the depletion of natural resources from the environmental pollution point of view and also it is essential for the sustainable development. Therefore, there is no wonder that the recycling is one of the best solutions sought. The recycling technology not only solves the problem of waste disposal, but reduces the cost and preserves environment also. In addition, the recycling and proper management of construction and demolition waste gives better opportunities to handle the other kinds of waste, as less land is used for dumping of construction and demolition waste.

Recycling of different materials has been tried in the past in different forms. Recycling of coarse aggregates, generated from the demolished or disaster driven waste concrete, has attracted the researchers in the recent past. Coarse aggregates, one of the important ingredients of concrete is becoming dearer in terms of the increasing cost of the materials and its availability. Hence, recycling of coarse aggregates is of utmost importance to overcome these difficulties. Thus this thesis focuses on using the demolition waste as recycled coarse aggregate (RCA) in the production of concrete. The Building Contractors Society of Japan (BCSJ 1978) had proposed the following terminology on recycled aggregate and recycled aggregate concrete (RAC).

Waste concrete: It is the concrete debris from demolished structures as well as the fresh and hardened concrete refused by ready-mix plants or site mix concrete producers or concrete product manufacturers.

Original concrete: It is the concrete from plain and reinforced concrete structures or precast concrete elements which can be used as raw material for the production of recycled aggregates.

Recycled concrete aggregates: These are the aggregates produced by the crushing of original concrete. These aggregates may be either fine or coarse recycled aggregates.

Recycled aggregate concrete (RAC): It is the concrete produced by using the recycled aggregates or the combination of recycled and natural aggregates.

In the present study the recycled coarse aggregates are obtained by crushing the old demolished Reinforced Cement Concrete (RCC) culverts and a demolished RCC slab of an old residential building.

1.2 Objective of the Present Thesis

The objective of the present thesis is "*the characterization of recycled coarse aggregate and study the macro, micro and structural behaviour of recycled aggregate concrete*."

1.3 Structure of the Thesis

The thesis is divided in 7 Chapters. The brief description of each Chapter is listed below.

Chapter 1 outlines the general introduction of the present investigation along with the objective of the work.

Review of the findings related to the use and characteristics of recycled aggregates and recycled aggregate concrete available in the published literature is presented in **Chapter 2**. In addition, the present world scenario of the construction and demolition waste is also addressed. Finally, the critical observations drawn from the existing literature are presented. The scope of the present work is identified based on the limitations in the area.

The detailed experimental investigation carried out in the present study is discussed in **Chapter 3.** Descriptions of the various instruments and test procedures adopted to investigate the properties of both recycled coarse aggregate and recycled aggregate concrete are also explained.

Chapter 4 presents the details about the physical and mechanical characteristics of natural and recycled coarse aggregates obtained from three sources. In addition, the influence of different percentages of recycled coarse aggregate obtained from each source separately on the fresh and hardened properties of concretes (both mechanical and durability) are discussed. The relationships developed amongst a few engineering properties are compared with the existing relationships of both normal concrete and recycled aggregate concrete. At the end the non-destructive test (NDT) results of RAC are also discussed.

Chapter 5 deals with the microstructural characteristaion of recycled aggregate concrete. In this the detailed specimen preparation procedure for scanning electron microscopic examination, brief description about the Scanning Electron Microscope (SEM), Backscatter Scanning Electron (BSE) image techniques and Vickers microhardness instrument are discussed. Finally the characteristics of Interfacial Transition Zone (ITZ) of both normal concrete and recycled aggregate concretes made with RCA obtained from all the three sources are addressed.

Chapter 6 describes the behaviour of recycled aggregate concrete under drop weight impact load. In this the details of the instrumentation, key findings and observations associated with them are discussed.

Chapter 7 summarises the important conclusions and recommendations for the future research.

Finally a list of references is appended.

1.4 Summary

The background of the present work is described in the present Chapter along with the terminologies which are used. In addition, the objective of the present work and the organization of the present thesis are highlighted.