Chapter 1

Introduction

Recycling of materials is not a recently developed practice. The need for recycling became apparent when the increasing demand for raw resources placed pressure on countries to become more conscious of the use of materials in all sectors. The construction and civil works industries account for 60% of worldwide consumption of the earth's raw natural resources (Bribian et al, 2011). The concrete industry is one of the largest consumers of earthly resources and energy. In 1995 global concrete production was in the region of 10 billion tonnes and was set to reach 16 billion tonnes by 2010 (Lui & Chern, 2008). Van Zijl (2010) stated that the concrete production worldwide was estimated at 12 billion tonnes per year and the construction and demolition (C&D) waste, excluding industrial waste, accumulated to 2 billion tonnes per year. This C&D waste is mainly sent to land fill sites, however a minority of C&D waste is reused and generally in low grade applications in the construction industry. South Africa's C&D waste sent to land fill is said to be over 1 million tonnes, which was derived from limited data (van Zijl, 2010). With such immense stress placed on natural resources and landfill sites worldwide the need for the development of alternative uses for C&D waste has led many countries to explore the possible uses to include more construction applications. According to Tam (2009) Japan is the leading country in the use of recycled concrete aggregate (RCA). Countries such as Germany, Switzerland, Netherlands, Denmark, Great Britain, USA and Russia all have established standards or specifications for the use of RCA in concrete (Dehn, 2007). These countries have created guidelines and specifications that make the addition of RCA in construction mandatory, thus reducing the impact on land fill sites and natural aggregate extraction. Currently South Africa does not have similar specifications and therefore there is a reluctance to use RCA in concrete mix design due to the uncertainty of its properties. There are companies such as Cape Brick which produce products using percentages of recycled aggregate; however these products have not been accepted because many engineers do not perceive that the products can meet the standards that natural aggregate can deliver. This leads to the necessity for the development of guidelines or specifications specifically for RCA so that the reliability of such a commodity can be ensured.

1.1 Research Aims

The aim of this research is to make recommendations and specify the potential use of coarse RCA as a material in structural concrete with possible guidelines and/or specifications. The shortage of knowledge and lack of specifications in South Africa are the main reasons for this research of RCA. By increasing the database of research of RCA in South Africa the possibility of specifications for this alternative building material can be initiated. The implications of such specifications would lead to RCA acceptance in concrete design and thus reducing the amount of C&D waste accumulating at landfill sites and decreasing the extraction of depleting natural aggregates from the earth.

1.2 Research Objectives

The objectives that are achieved through this research project are firstly, what is the percentage replacement of RCA to a concrete blend that will produce a material that achieves similar or better results than a concrete blend containing natural aggregates. Secondly, what aggregate properties and limits should be defined in the specification of RCA for it to be accepted as a material in a concrete mixture.

These objectives will be accomplished by assessing the aggregate properties of RCA at predetermined percentages mixed with natural aggregate as well as the properties of fresh and hardened states of concrete. A literature review of RCA and C&D waste will provide knowledge and guidelines to assess the outcomes of the tests performed in this research.

The objectives can be summarized as follows:

- An overview of the use of recycled materials in modern construction and the influence thereof on sustainable development.
- A comprehensive literature study into the aggregate, fresh and hardened concrete properties to gain an understanding of the possible outcomes from the experimental programme.
- A study into the current standards and specifications applicable to recycled materials for the recommendation of RCA in South Africa.
- A well-defined experimental programme to ensure all the necessary methods and testing procedures are utilised.
- An investigation into the aggregate properties and the influence of RCA replacement on these properties.
- The influence that the RCA will have on fresh concrete.
- Examining the impact which RCA will have on the mechanical, durability and dimensional properties of hardened concrete.

- Finally, conclude and recommend limits and specifications for the aggregate properties, as an inclusion into the current South African standard for aggregates.

1.3 Research Scope

This research will focus mainly on coarse RCA because the inclusion of fine RCA is not recommended in concrete mixtures as noted in Chapter 3. The RCA samples were collected at intervals over a 5 month period and sourced from the company Cape Brick. Cape Brick receives sorted and sized RCA from various construction and demolitions sites within the greater City of Cape Town. This material is processed through various crushing and sorting stations to produce both coarse and fine aggregates.

The main focus of this research is on the aggregate properties and their influence on the fresh and hardened concrete properties. The aggregate properties to be investigated included grading, dust content, fineness modulus, particle shape and surface texture, flakiness index, loose bulk and compacted bulk density, relative density, water absorption, aggregate crushing value, constituents of coarse RCA, chemical analysis for water soluble cations and anions and the chemical mineralogy through an XRF analysis.

The aggregates were mixed with other concrete constituents at replacement percentages of: 0, 15, 30, 50 and 100%. The natural aggregates used in the experimental programme was 19mm Greywacke as coarse aggregate and Malmesbury sand as fine aggregate. The binders include: CEM I 52.5 N cement and Corex® slag (GGCS), both available from the same cement producer. A water:binder ratio of 0.6 was used for all the concrete mixes and no admixtures are used.

The fresh concrete properties examined after mixing the relevant constituents once combined with water were the workability and loss of workability, fresh density and the air content. The fresh concrete is cast into the relevant mould and cured for a specified period at which point the hardened concrete properties were inspected. The hardened concrete properties investigated included the: compression strength, tensile splitting strength, oxygen permeability, water sorptivity, chloride conductivity, modulus of elasticity, shrinkage and creep. These properties are divided into mechanical, durability and dimensional properties to isolate the possible effects that the aggregate may have.

1.4 Research Layout

Chapter 2 describes the sustainability of construction materials and the issues surrounding the consumption of natural resources and the damaging effects of the construction industry. Construction and demolition waste and the methods of recycling this material to produce recycled aggregates are discussed in general. The applications of recycled concrete aggregate (RCA) are briefly described. The waste management in South Africa and the amounts of resources utilised (recycled and natural) are provided, with reference to a brick manufacturing company which uses recycled aggregates.

A comprehensive review of aggregate, fresh concrete and hardened concrete properties is given in Chapter 3. Research and investigations into the influence of RCA on above mentioned properties are reviewed from various sources. The South African and international standards and specifications used to classify aggregates for concrete are finally covered with particular relevance to RCA.

The experimental programme is explained in Chapter 4. The details outlining the materials used and tests for the aggregate, fresh and hardened concrete properties are provided. The concrete mixture design, mixing procedure and concrete production required to produce the test specimens for the relevant tests are defined.

Chapter 5 details the test methodologies necessary to examine the aggregate properties. The results from the various tests according to the geometrical, physical and chemical properties are analysed and studied with reference to the information found in Chapter 3.

The fresh concrete properties test methodologies and results relating to the workability and consistency of concrete are covered in Chapter 6. The slump, slump loss with time, air content and fresh density are evaluated and compared to the investigations dealt with in Chapter 3.

In Chapter 7 the hardened concrete properties from this investigation are examined. The test methodologies are described in detail with the inclusion of the design and manufacture of creep testing apparatus (creep frame) which was completed during this investigation. The results for the mechanical, durability and dimensional properties are analysed and deliberated according to the research found in Chapter 3.

Finally, Chapter 8 covers the general conclusions and discussions reviewing the information and results found in the previous chapters. From the knowledge and information gained from this investigation a proposal for possible guidelines and/or specifications for RCA properties in concrete are provided. To finish, recommendations for further research into various aspects of RCA are discussed and proposed.