The use of fibre reinforced concrete construction essay

Within the following dissertation I aim to study the use of Fibre Reinforced Concrete within the construction industry.

Over the last decade, fibre reinforced concrete (FRC) has become widely used in different structural and non-structural applications such as pavements, floors, overlays, industrial slabs and shotcrete linings etc where the major concern is toughness and first crack in flexure. It is estimated that more than 150 000 metric tonnes of FRC has been used throughout this duration of time.

Particular focus will be made as to the current uses of FRC within the construction industry whilst trying to identify what the future hold for this composite material.

The question will be posed at to what the general consensus is within the construction industry in regard to the use of fibre reinforcement within concrete.

1. 2 Concrete and Fibre Reinforcement

Concrete is a material that is very strong in compression, but relatively weak in tension. To compensate for this imbalance in the concrete’s behavior, an appropriate reinforcement must be cast into the concrete to help carry the tensile loads.

Two forms of reinforcement commonly used are Steel Fabric (Rebar) reinforcement and Fibre reinforcement.

Steel Fabric Rebar/Mesh has been used for many years in construction to reinforce concrete and is usually made of carbon steel which is cast with

ridges for better adherence to the concrete. Steel expands and contracts at the same rate as concrete, eliminating cracking issues that might come from materials that expand and contract at different rates whilst strengthening the overall structure.

An exciting alternative product which could be used would be that of Fibre reinforcement.

The idea of using a fibrous material to provide tensile strength to a material strong in compression but brittle loses itself in the mists of time; in ancient Egypt straw was added to clay mixtures in order to provide brick with enhanced flexural resistance, thus providing better handling properties after the brick had dried in the sun.

Fibre reinforced concrete is a compound consisting of a cementitious hydrated paste into which reinforcement fibres such as small steel/polymer filaments about the size of a paperclip are mixed.

The multiple fibres redistribute the forces within the concrete, restraining the mechanism of formation and extension of cracks. The result improves the ductility of the concrete which is able to maintain a residual capacity in the post cracking phase. The fibres within the concrete literally ‘ stitch’ the sides of a forming crack together.

Although fibre reinforced concrete has been widely used throughout Western Europe and beyond, its application in the UK is, so far, relatively limited, with industrial floors being the most common application. The lack of formally accepted design standard may be an influence on the situation although

calls are being made for clear industrial guidelines. The Concrete Society Technical Report 63 addresses many of the issues and points the way forward for future design.

1. 3 Aim

The main aim of the following theses is to investigate and evaluate the various properties and functions of Fibre Reinforced Concrete (FRC) throughout the construction industry whilst giving consideration as to what lies ahead for the future of FRC.

1. 4 Objectives

To provide a historic overview of Concrete and Fibre Reinforcement.

To identify and analyze the various types of fibre products available for concrete reinforcement.

To establish possible concrete mix performance enhancements associated with FRC.

To explore the Construction Management criteria within the industry in relation to the use of FRC.

To highlight the future possibilities and potential that FRC has within the construction industry whilst seeking the views and opinions of various construction professionals.

1. 5 Rationale for Research

There are three main reasons why this particular topic has been chosen for this theses along with the required research which has been carried out, these are:

A personal interest in the material of concrete along with its various functions and applications due to work experience gained in this field.

An interest in new innovations being made available to the construction market which will enhance the overall application of the material.

An aspiration to investigate whilst enhancing my current knowledge on the theory of FRC

1. 6 Methodology

Due to the nature of the topic to meet the aims and objectives previously set out for this thesis and to establish the direction for this piece of work information has been obtained from the following sources.

Primary Literature Academic Research Journals (Refereed)

Conferences / Seminars (Referred)

Government Publications

Technical Report Papers

Secondary Literature Construction Journals

Construction Textbooks

Library Search Indexes and Abstracts

Internet / World Wide Web

Library Catalogue

Case Study A case study of fibre reinforcement with regard to

Construction Management criteria will also be analyzed via various site visits prior and during any works being carried out.

This will provide a valuable insight as to how this product is perceived whilst strengthening the case for use in the future.

Questionnaire Questionnaires will also be distributed to various

Professional bodies influenced by the use of FRC within the construction industry.

The methodology adopted is fully discussed afterwards in Chapter 4 along with the analysis of the research findings in Chapter 5.

1. 7 Chapter Overview

Chapter 1: Introduction

Provide a brief introduction into the areas of study which have been identified by the author whilst outlining the main aims and objectives to be achieved in order to fulfill the research criteria.

Chapter 2: Background for Study (Literature Search)

Chapter 3: Case Study

On site Case Study (tbc)

Chapter 4: Methodology

An evaluation of the types of research and methodology methods carried out in order to achieve the aims and objectives previously stated.

This will describe how and why the chosen research methods had been adopted.

Chapter 5: Data Interpretation and Analysis

This will consist of an analysis of the data and information generated from the questionnaire returns using relevant diagrams, tables and text to illustrate all findings.

Chapter 6: Conclusions and Recommendations

All findings from the research process will be compiled and it will be observed as to whether the main outlined objectives have been realized.

Recommendations will also be given on areas of further research to enhance the material within the theses.

CHAPTER 2

A REVIEW OF FIBRE REINFORCED CONCRETE

2. 1 History of Concrete and Fibre Reinforcement.

The history of composite materials started in ancient Egypt over 2000 years ago with mud bricks, reinforced with straw fibres. Fast forward to more recent times where it has moved through the applications of asbestos fibre

cement – widely used during the 20th Century – and continued with the highly sophisticated carbon fibre type materials of the aerospace and specialist automotive industries.

In the 1960’s, studies by Industrial scientists Romauldi, Mandel and others, established the theoretical and experimental foundations for the development of steel fibre as a medium to reinforce concrete.

In 1973, James Romauldi, with Battelle Development Corporation of Columbus, Ohio (USA), patented the principles of steel fibre reinforced concrete, creating what was an essentially new material for civil engineers. (Crowther, 2007) 6

Glass fibres were introduced and research continued into harnessing the properties of synthetic fibres such as polypropylene.

By 2000, the first ‘ macro fibre, concrete was ready for production from various suppliers. (Tarmac, 2009)7

Fibre reinforced concrete is now widely used throughout the world on major infrastructure works, tunnels, underground railways and large reinforcement structures. In the UK, its use is most widespread in large industrial floors

The improved impact resistance characteristics are especially beneficial in applications where high or aggressive traffic loads are expected.

The table below clearly shows how concrete is affected by the addition of fibres in various application fields:

Table from concrete society

(Illston & Domone, 2001) state that ‘ Concrete is an ever present material and its versatility, comparative cheapness and energy efficiency have ensured that it is of great and increasing importance for all types of construction throughout the world’. 1

Many structures have concrete as their principal material, albeit as a composite with steel to give either reinforced or prestressed concrete, even in those structures where other materials such as steel or timber form the principal structural elements, concrete will normally still have an important role, for example in the foundations.

In its simplest form, concrete is a mixture of cement, water and aggregates in which the cement and water have combined to bind the aggregate particles together to form a monolithic whole.

Even though our knowledge and understanding of the material is far from complete, and research continues, concrete has been successfully used in many cultures and in many civilisations.

It is not just a modern material; the oldest concrete discovered so far is in southern Israel, and dates from about 7000 BC. It was used for flooring, and consists of quicklime, made by burning limestone, mixed with water and stone which set into a hardened material. (Sutherland, 2009)2

Steel Fabric Rebar/Mesh has been used for many years in construction to reinforce concrete and is usually made of carbon steel which is cast with ridges for better adherence to the concrete. Steel expands and contracts at

the same rate as concrete, eliminating cracking issues that might come from materials that expand and contract at different rates whilst strengthening the overall structure.

Rebar comes in several different lengths and thicknesses to accommodate different types and sizes of jobs. They can be tied together to form a grid or cage, which is particularly useful for larger projects or alternatively mesh can be delivered in various standard sheet sizes. (Romtech, 2009)3

Fibres mixed into the concrete can provide an alternative to the provision of conventional steel bars or welded fabric in some applications. The concept has been in existence for many years (the first patent was applied for in 1874) and it has been used in a range of applications: amongst the first major uses was the patching of bomb craters in runways during World War 2. However, it was during the 1970's that commercial use of this material began to gather momentum particularly in Europe, Japan and the USA. (Clark, 2007) 5

2. 2 Types of Fibre Products used For Concrete Reinforcement

Although there are numerous fibre products on the market the most commonly used fibre types are shown and discussed below giving information on the manufacturer of the fibre, its properties, fibre content in applications and the effects of the fibre type on concretes and mortars.

Steel Fibres

‘ Concrete containing steel fibres has been shown to have substantially improved resistance to impact and greater ductility of failure in compression, flexure and torsion.’ (ACI Special publication sp-44)

Bentur, A. and Mindess, S. Fibre reinforced cementitious materials, London: Elsevier, 1990

Steel fibres have been used in concrete since the early 1900’s with early fibres being round and smooth and the wire was cut or chopped to required lengths.

The use of straight, smooth fibres has largely disappeared and modern fibres have either rough surfaces, hooked ends, crimped or are undulated through there length.

Modern commercially available fibres are manufactured from drawn steel wire, slit steel sheet steel or by the melt – extraction process with produces fibres that have a crescent shaped cross section.

TR63 reports that

Steel fibres are produced by various processes as discussed above and are supplied in many different shapes and sizes as is shown below in Figure 1. They may either be straight or deformed, however most are round in cross – section with diameters between 25 and 60 mm. Steel fibres have a tensile strength typically 2-3 times greater than that of traditional fabric reinforcement and a significantly greater surface area (for a given mass of steel) to develop bond with the concrete matrix.

Figure 1

The configurations of fibres can be either straight, continuous-deformed, or end formed as shown previous. Initially, straight fibers were the only configuration of steel fibers available. After further investigation it was quickly learned that there bonding potential was limited which restricted there expected contribution to the engineering properties of concrete.

New products were developed to increase the bond between the fibre and concrete, the two best configurations which emerged were: A hooked end, draw wire fibre and a continuously deformed, slit sheet steel fibre.

It was determined that the continuous deformed, slit sheet steel fibre provided better micro macro cracking performance as well as flexural strength enhancement, whereas the end deformed, drawn wire steel fibre performed best post first crack.

It has been reported that steel fibre reinforced concrete, because of the improved ductility, could find applications where impact resistance is important. Fatigue resistance of the concrete is reported to be increased by up to 70%.

The addition of steel fibres as supplementary reinforcement in concrete can assist in the reduction of spalling due to thermal shock and thermal gradient

Some of the physical characteristics of fibres directly affect key aspects of concrete performance while others are less important. The factors considered to have the strongest influence on the performance of the steel fibre in concrete are:

Bond and Anchorage mechanisms (e. g. straight or deformed shape, end cones or hooked ends)

Fibre length and diameter.

Dosage used in concrete pours. (kg/m3)

Fibre count (number of fibres per kg of fibre), which is a function of fibre size and dosage.

Tensile Strength

Elastic Modulus

Hannant outlines that fibres in concrete act in various ways. Firstly they can remove the formation and development of cracks due to early age plastic settlement and drying shrinkage. Secondly, they may provide a degree of post cracking load carrying capacity.

The mechanisms are as follows:

Steel fibres, being randomly distributed in the concrete, intercept micro – cracks as they form, inhibiting the tendency for them to form into larger cracks.

After cracking, the fibres spanning the crack will provide a residual load carrying capacity. The capacity can be considerable, depending on dosage and the type of fibre used.

References:

Illston, J. M. and Domone, P. L. J. (2001) Construction Materials – There Nature and Behavior 3rd Edition. P91. Spon Press.

Sutherland, M. (2009) Concrete Engineering International Volume 13 Number 2. Summer 2009. The Concrete Society

Romtech. (2009) Technical Support Products accessed 30th October at http://www. rom. co. uk/products. aspx

Crowther, D. (2009) Concrete for the Construction Industry Journal Volume 43 Number 3 April 2009. The Concrete Society.

Clark, J. (2007) Technical Report No. 63 Guidance for The Design of Steel Fibre Reinforced Concrete. Camberley

Tarmac. (2009) ‘ Topforce Fibre Reinforced Concrete’ accessed 12 November at www. tarmaconline. com/…/0982%20Tarmac%20Fibre%20Reinforced %20Concrete%20Brochure. pdf.

Propex. (2006) ‘ Propex Concrete Systems’ accessed 13 November at www. CS-500_Propex%20Concrete%20Systems%20Brochure_Jul%2006(1). Pdf.