Chapter 1

Introduction

1.1 Background

Steel Fiber Reinforced Concrete (SFRC) is defined as concrete containing randomly oriented discontinuous discrete steel fibers.

Historically, many types of fibers have been used to reinforce brittle materials. Straw was used to reinforce sun-baked bricks; horse-hair was used to reinforce plaster and more recently, asbestos fibers are being used to reinforce Portland cement [1]. At various intervals since the turn of the 20th century short pieces of steel have been included within concrete in an attempt to increase the tensile strength and ductility [2]. Studies to determine strength properties of SFRC and mortar began in the laboratories of the Portland Cement Association in the late 1950's [3]. During the late 1960's and early 70's, fiber reinforced concrete was studied and tested extensively, and subsequently was used in a variety of demonstration projects in the USA [4].

Although the technology has been broadly accepted and the advantages of the SFRC are well recognized, the actual practical usage in South Africa is still in its young stages. The real usage of SFRC started in1992, when a hundred segmented SFRC rings (with fiber dosage of 50 kg/m^3) were used in the Delivery Tunnel North (D.T.N.) section of Lesotho High Water Project (L.H.W.P.). This tunnel was designed to secure future water supplies to the area of Pretoria and Johannesburg. It is stated that the inclusion of the steel fiber has reduced shrinkage cracks and the incidents of corner break-offs compared to the very first segments at the beginning of the project where rings contained no steel fibers [5].

This research contains a discussion of the behavioral properties of the SFRC and the possible effects of theses properties on the performance of ground slabs constructed with the material.

The cost is always the major issue controlling designs and development of infrastructure. A reduction of design thickness and increasing the maintenance intervals are normally associated with SFRC. Optimizing the strength and fatigue characteristics, which is possible by using various steel fiber dosages, can minimize the cost.

The focus of this research is to evaluate the capacity and behaviour of SFRC used for ground slabs. The evaluation was conducted using a comparative approach, on which two full-scale slabs were theoretically and physically analyzed.

1.2 Objectives of Study

The general objective of this research is to evaluate the usage of SFRC for ground slabs and to give broader ideas about its behaviour in comparison to that of normal conventional concrete. The core objectives are to:

- Determine the influence of the steel fiber dosage on the properties of concrete. The properties measured include workability, compressive strength, modulus of rupture, modulus of elasticity and toughness characteristics.
- Compare the bearing capacity, deformation characteristics and mode of failure of slabs with and without steel fibers. The comparison is also aimed to evaluate the influence of low dosages SF (as low as 15 kg/m^3).
- Compare the strength development, mode of failure of the concrete used in the slabs and compare the measured values to theoretical values.
- Compare the calculated results using theoretical models of Westergaard, Meyerhof, Falkner et al and Shentu et al to the measured results from the full-scale test and to assess the capability for each model when applied to the SFRC.

1.3 Scope and Limitations of Study

The scope of this research covers plain concrete and SFRC mixtures fabricated using Portland cement, pozzolan, fine and coarse aggregates and water. Hook-ended steel fibers with various contents (ranging between 0 and 30 kg/m^3) are added to manufacture the SFRC mixture.

The effect of steel fiber dosage on workability, compressive strength, modulus of rupture, modulus of elasticity and toughness characteristics is studied using mixtures containing steel fiber dosage between 0 and 30 kg/m^3.

Two slabs, the first slab containing 15 kg/m^3 of steel fiber and second slab containing no fiber is loaded at four points on each slab. Slabs are subjected to a curing condition similar to those found in normal construction sites. Specimens are either cast or taken from the slabs. The cast samples had standard curing conditions while the sawn or cored ones had curing conditions similar to the slabs.

Only a semi static loading scenario is investigated, with the load applied gradually at a low rate. In the case of full-scale testing, only single loading plate configuration is considered.

The two slabs are not completely simulating the field situation because of the limited dimensions, unconstrained edges and corners. Moreover, the subgrade reaction of the underlying layers is greater than the usual values found in the field. The stiff foundation consists of solid floor and foam concrete subbase layers.

The literature is also reviewed from a ground slabs perspectives. Many aspects concerning SFRC not relevant to ground slabs are not discussed or included. Several theoretical methods are found, but only four theoretical methods are included and used in the comparative study. These models are Westergaard, Meyerhof, Falkner et al, and Shentu et al.

1.4 Study Methodology

Steel fibers with dosages ranging between 0 and 30 kg/m^3 are added to a 30 MPa mix. Standard beams and cubes are cast for each fiber dosage and tested for tensile strength at 28 days and compressive strength at 7 and 28 days respectively.

For the slab test, two approaches were followed by this research to compare the SFRC and the plain concrete:

(a) Experimental approach

(b) Analytical approach

In the experimental approach, full-scale slab tests are conducted on two slabs having identical mix (30 MPa). The first is a plain concrete slab 150mm thick and the second is a SFRC slab 125mm thick containing 15 kg/m^3 hook-ended steel fibers. Both slabs are subjected to interior edge and corner load. The interior of the slabs is loaded after 28 days while the edges and corners are tested after 90 days. Cores are drilled from the slabs and tested for compressive strength. Beams are sawn from the edge, interior and tested for tensile strength. The cores and beams are tested after 90 days at the time of testing the edges and corners.

The analytical approach utilized either measured or fairly estimated data to serve as inputs to theoretical models of Westergaard, Meyerhof, Falkner et al and Shentu et al. Theoretical analysis is performed using these four models to compare the measured load capacities and deflection with the calculated ones.

1.5 Need for research in this field

The rapid increase in traffic and load on pavements in the recent years, necessitate some sort of modifications to pavement materials to cope with these new issues. SFRC could improve engineering properties, resulting in better performance under traffic and load.

Despite of the wide range of lab information available, the information is fragmented and research concentrate on SFRC as material rather than its applications.

Full-scale tests are more realistic and give a broader idea about the tested element. They are also more relevant to the field of pavements. Few tests are conducted to clarify and address issues such as load capacity and deformation characteristics for the SFRC.

This research is essential; as similar tests and investigations using the South African material are rare or/and not exists.

1.6 Organization of Dissertation

The dissertation has been divided into ten chapters as follows:

Chapter 1: serves as an introduction to the dissertation.

Chapter 2: consists of an introduction to the steel fibers and SFRC. The engineering properties of the SFRC are also discussed.

Chapter 3: the SFRC pavement design methods, distresses, review for previous projects and economical implications are included.

Chapter 4: includes the basic theoretical analysis methods used in the comparison between SFRC and plain concrete. It also contains the similar previous full-scale tests conducted by other researchers.

Chapter 5: contains the experimental procedure and tests setting.

Chapter 6: contains the study of the influence of steel fiber dosage on mechanical properties of concrete

Chapter 7: contains the results and discussion of the full-scale slab tests.

Chapter 8: contains the result and discussion of the comparison between practice and theory.

Chapter 9: contains the ultimate conclusion of the study and the recommendations.

Chapter 10: comprises the list of references.

Chapter 11: appendices contain various calculations, tables and design formulas are provided in this chapter and referred to the main body and after body of the dissertation.