

CE 13/47

18/00N/54/2015

DCE 21/52

# APPLICABILITY OF STEEL FIBERS TO IMPROVE THE PROPERTIES OF CEMENT STABILIZED AGGREGATE BASES

LIBRARY  
UNIVERSITY OF MORATUWA, SRI LANKA  
MORATUWA

M. S. K. De Silva

(108606D)

Degree of Master of Engineering

*in Highway & Traffic Eng.*

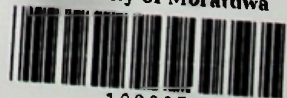
Department of Civil Engineering

University of Moratuwa

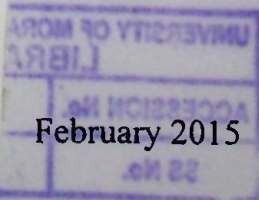
Sri Lanka

624 "15"  
625 + 656 (0+3)

University of Moratuwa



108997



February 2015

108997

+  
CD-ROM

TH2898

108997

## DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any University to the best of my knowledge and belief and it does not contain any material previously published, written or orally communicated by another person or myself except where due reference is made in the text. I also hereby give consent for my dissertation, if accepted, to be made available for photocopying and for interlibrary loans, and for the title and summary to be made available to outside organizations.

*UOM Verified Signature*

*27.02.2015*  
.....

Signature of the Candidate

Date

To the best of my knowledge, the above particulars are correct.

.. *UOM Verified Signature* ..

Supervisor

## ACKNOWLEDGMENT

I gratefully acknowledge my sincere gratitude to my supervisor, Dr. W.K. Mampearachchi, University of Moratuwa for giving me the opportunity to undertake this research study and providing valuable advice and support throughout the research study. My special thanks go to Prof. J.M.S.J Bandara too.

I do thank Mr. Gajaba Gunawardena, the Project Director of Project Management Unit of World Bank funded Road Sector Assistant Project, for releasing me to study for this degree on part time basis.

The guidance and immeasurable support given by Mr. Wijaya Bandara is acknowledged gratefully. I also like to appreciate the support from Mr. Nadeesha Abeysinghe (MAGA Engineering) and Miss. G.A.C. Priyadharshani (Ministry of Finance). I owe a very special gratitude to Mr. Yasas Ratiyala (FINCO ENGINEERING Pvt. LTD) for his valuable support.

I specially thank Mr. Yohan Indika, Miss Melani Jayakody and all the staff in Highway and Transportation Engineering Division of the Department of Civil Engineering, University of Moratuwa. I also like to appreciate the invaluable support given by Mr. Lenus (Structural Laboratory of Department of University of Moratuwa) throughout the laboratory test series.



## ABSTRACT

Stabilized bases are normally designed for the heavy traffic categories or in the absence of base materials which should have the required material properties according to the specifications so that the higher strength category can be achieved.

Bases can be constructed using soil or aggregates. Those are stabilized with various admixtures such as lime, sand or cement. Among them, cement stabilization is a common practice in road construction industry.

The road construction industry has the experiences about the stabilization of dense graded aggregate bases with cement. Even though the content of cement has to be increased to get the higher strength capacity, shrinkage cracks may appear with the increase usage of the cement content and it has a tendency to convert the layer to a rigid pavement too. Hence, another feasible technique should be applied to achieve the required higher strength capacities concurrently to diminish shrinkage cracks and form the base withstand against higher number of heavy load repetitions as well as form the base withstand against higher number of heavy load repetitions without converting the layer into rigid.

To achieve both phenomena, this research was carried out to introduce usage of a reinforcement type such as steel fibers in Dense Graded Aggregate bases.

In this study, it is discussed about the high performance of Steel Fiber Reinforced Cement Stabilized bases over the conventional Cement Stabilized Bases.

Based on the results, a Pavement Design Chart was developed for Steel Fiber Reinforced Cement Stabilized Bases suitable for higher Traffic Classes such as T7 and T8. This can be used in general practice without doing any calculations.

## TABLE OF CONTENTS

Declaration of the Candidate	i
Acknowledgments	ii
Abstract	iii
Table of contents	iv
List of Figures	vii
List of Tables	ix
<b>CHAPTER 01 INTRODUCTION</b>	<b>01</b>
1.1 Problem Statement	01
1.1.1 Introduction	01
1.1.2 Methodology	02
1.1.3 Expected Outcome	02
<b>CHAPTER 02 LITERATURE REVIEW</b>	<b>03</b>
2.1 Stabilized Bases	03
2.2 Steel Fibers	05
2.3 Steel Fiber Reinforced Cement Concrete	05
2.4 Steel Fibers used in Cement Stabilized Bases	06
2.5 Effect of Steel Fibers in Conventional Concrete	07
2.6 Effect of Steel Fiber on Flexural capacity of R/F Concrete Beams	12



<b>CHAPTER 03 METHODOLOGY .....</b>	<b>30</b>
3.1 Overview.....	30
3.2 Mix Design.....	31
3.3 Test Procedure.....	33
3.3.1 Selection of Cement Content.....	33
3.3.2 Selection of Water Content.....	34
3.3.3 Selection of Steel Fiber Content.....	34
3.3.4 Preparation of the Specimens and Tests carried out.....	34
3.3.5 Observations.....	38
<b>CHAPTER 04 DATA ANALYSIS &amp; RESULTS .....</b>	<b>39</b>
4.1 Comparison of Flexible Strength of the Beams with and Without Steel Fibers.....	39
4.2 Comparison of Crushing Strength of the Beams with and Without Steel Fibers.....	40
4.3 Development of a Relationship between Flexural Strength & Crushing Strength.....	41
4.4 Development of a Traffic Category for relevant cement content.....	43
4.5 Analysis for different Sub Grade strengths.....	50
4.6 Develop Pavement Design Structures with SFCSB for Medium and Higher Traffic Categories .....	52
4.7 Economic Analysis .....	54

4.7.1 General .....54

4.7.2 Cost Analysis for Road Pavement Structures with Steel Fiber  
Reinforced Cement Treated Bases .....54

4.7.3 Cost Analysis for Road Pavement Structures in Chart 3 and 5 in  
Road Note 31 .....57

**CHAPTER 05 CONCLUSION .....58**

5.1 Comparison of flexural and crushing strength in steel fiber reinforced  
bases over conventional cement stabilized bases..... 58

5.2 Develop a co-relation between flexural and crushing strengths of  
steel fiber reinforced bases..... 59

5.3 Comparison of the increment patterns of no. of repetitions obtained  
from the bases with and without steel fibres..... 59

5.4 Develop a Pavement Design Structures with SFCS Bases for Different  
Traffic Categories .....61

5.5 Economic Analysis .....62

## LIST OF FIGURES

Fig. 2.1: Variation of Compressive strength with respect to % of fiber content .....	09
Fig. 2.2: Variation of Flexural strength with respect to % of fiber content .....	09
Fig. 2.3: Variation in Slump of concrete with respect to % of fiber content .....	10
Fig. 2.4: Steel Fiber Reinforced concrete .....	11
Fig.2.5: Crack observed in specimen .....	11
Fig. 2.6: Influence of amount of steel fibres on the compressive stress behavior .....	13
Fig. 2.7: Effects of Steel Fibres Content on Compressive Stress-Strain Curve of FRC (Padmarajaiah and Ramaswamy, 2002) .....	14
Fig 2.8: Steel Fiber Winrad @FS7_II Used in This Study .....	15
Fig 2.9: Cross Section of RC Beams .....	16
Fig. 2.10: Concrete with 1% Steel Fiber FS7_II .....	18
Fig. 2.11: Failure of cylinder in compressive test at 28 <sup>th</sup> days .....	19
Fig 2.12: Linear Regression (a) and (b) .....	20
Fig 2.13: Schematic of Typical Fracture Patterns under Bending .....	23
Fig 2.14: Schematic of Typical Fracture Patterns under Bending .....	23
Fig.3.1: Dramix Steel Fibres .....	34
Fig.3.2: Casted Beam specimen .....	35
Fig.3.3: Testing Machine .....	36
Fig.3.4: Beam to be tested is positioned on the machine .....	36
Fig.3.5: The crack was initiated at the bottom and propagated upwards .....	37



Fig.3.6: The cracked surface of the tested beam .....	37
Fig. 4.1: Flexural Strength Vs Cement Content .....	39
Fig. 4.2: Crushing Strength Vs Cement Content .....	40
Fig. 4.3: The Graph of Flexural Strength Vs Crushing Strength using SPSS .....	41
Fig. 4.4: The Model Summary and coefficients given by SPSS software .....	42
Fig. 4.5: Increment of No. of Repetitions Vs Cement Content .....	43
Fig. 5.1: No. of Repetitions Vs Cement content (150mm thick) .....	60
Fig. 5.2: No. of Repetitions Vs Cement content (175mm thick) .....	60
Fig. 5.3: No. of Repetitions Vs Cement content (200mm thick) .....	61

## LIST OF TABLES

Table 2.1: Specification of Steel Fibers which Used in This Study .....	15
Table 2.2: The specification of the Mix Proportion .....	17
Table 2.3: Compressive Strength of Normal and Steel Fiber added Concrete cylinder .....	18
Table 2.4: Flexural Strength of Normal and Steel Fibre 1% Added Concrete Beam .....	21
Table 2.5: Compression of t-test Flexural Strength at 28 day .....	22
Table 2.6: Comparison the Flexural Strength and First crack, Model 1, Model2, Model3 ...	25
Table 2.7: First peak load, Net deflection at First peak load .....	26
Table 2.8: Residual load at net deflection .....	26
Table 3.1: Properties of Cement Stabilized materials .....	32
Table 3.2: Desirable properties of Dense Graded aggregate material before stabilization ...	33
Table 3.2: Desirable properties of Dense Graded aggregate material before stabilization ...	38
Table 4.1: Flexural Strengths of beams with and without Steel Fibres .....	39
Table 4.2: Crushing Strengths of Cubes with and without Steel Fibres .....	40
Table 4.3: Flexural Strength and Crushing Strength in N/mm <sup>2</sup> .....	41
Table 4.4: Flexural Strength of the beams with and without Steel fibres for various Cement Contents .....	46
Table 4.5: Fatigue and Rutting Analysis .....	48
Table 4.6: No. of Repetitions in Millions for 2% Sub grade CBR obtained from 'KENPAVE' Software .....	49
Table 4.7: The Traffic Classes obtained for various Layer Thicknesses .....	49



Table 4.8: No. of Repetitions for different layer thicknesses for Sub Grade CBR values	
Of 3%, 5% and 8% .....	50
Table 4.9: No of Repetitions in millions at different sub grade strengths .....	52
Table 4.10: Pavement Design Details for different Traffic Classes .....	53
Table 4.11: Design Details of SFSC Bases .....	53
Table 4.12: Cost Analysis of Road Pavement Structures with SFCS Bases in Rs/m <sup>2</sup> .....	56
Table 4.13: Cost Analysis of Road Pavement Structures in Road Note 31 in Rs/m <sup>2</sup> .....	57
Table 5.1: Cost Comparison in Rs/m <sup>2</sup> between RN 31 and Research Outcome .....	62