FLEXURAL PERFORMANCE OF STEEL FIBER REINFORCED CONCRETE BEAM

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I dedicate this work

To my parents

Late Alhaji Muhammad Mallum

And

Hajiya Fadimatu Muhammad Mallum (Hajja Barkindo)

Whose love, kindness, patience and prayer have brought me this far. I thank them

For their love, understanding and support throughout my endeavors

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ABSTRACT

Steel fibers are generally used as resistance of cracking and strengthening of concrete. According to previous research, it has been found that steel fiber (SF) reinforced concrete beam had higher flexural strength compared to conventional reinforced concrete beam. In this research, flexural performances of steel fiber reinforced concrete beams were studied for concrete grade 35. Optimum fiber content was found to be 1% and this was determined using compressive strength test with different SF dosages (0%, 1% and 2%). Mechanical properties of steel fiber reinforced concrete were determined through compressive strength, tensile strength and flexural strength. The result indicates that there is a slight increment in compressive strength and splitting tensile strength of SFRC of about 15% and 30%, respectively compared to control sample. The flexural strength shows a significant increase of more than 100% at 28 days compared with the control sample. The flexural behavior of steel fiber reinforced concrete beams at 28 days were studied under four points loading and the results were compared with conventional reinforced concrete beam. Beam 1 and Beam 3 failed at almost the same ultimate load. This shows that reinforcing the tension zone only has the same effect to that of reinforcing in both tension and compression zones. Beam 2 with steel fiber has slightly higher ultimate load, although the area of reinforcement was reduced. The use of steel fiber in concrete shows a significant improvement on the ductility and stiffness characteristics of the beams than the control beam.

ABSTRAK

Gentian keluli selalu digunakan untuk meningkatkan ketahanan konkrit terhadap keretakan dan penguatan konkrit. Penyelidikan yang lepas menunjukkan penggunaan getian keluli dapat meningkatkan kekuatan lenturan dibandingkan dengan konkrit bertetulang biasa. Dalam kajian ini prestasi lenturan konkrit bertetulang gentian keluli dikaji menggunakan konkrit Gred 35. Kandungan optima gentian keluli yang diperolehi dan digunakan adalah 1% ditentukan menggunakan ujian kekuatan mampatan dengan kandungan gentian berbeza (0%, 1% dan 2%). Sifat-sifat mekanikal konkrit bertetulang bergentian keluli dikaji melalui kekuatan mampatan, kekuatan tegangan dan kekualatn lenturan. Keputusan menunjukkan peningkatan terhadap kekuatan mampatan dan tegangan masing-masing 15% dan 30%, berbanding dengan sampel kawalan. Kekuatan lenturan menunjukkan peningkatan lebih dari 100% pada umur 28 hari berbanding dengan sampel kawalan. Kelakunan lenturan rasuk konkrit bertetulang bergentian keluli pada umur 28 hari ditentukan menggunakan ujian empat titik dan keputusannya dibandingkan dengan rasuk kawalan. Rasuk 1 dan Rasuk 3 merekodkan kekuatan yang lebihkurang sama semasa gagal. Ini menunjukkan penggunaan gentian keluli pada kawasan tegangan sahaja menghasilkan kesan yang sama berbanding dengan penggunaan gentian keluli pada kedua-dua kawasan tegangan dan mampatan. Rasuk 2 yang mempunyai gentian keluli merekodkan kekuatan yang lebih walaupun mempunyai luas tetulang tegangan yang kurang. Penggunaan gentian keluli dalam konkrit menunjukkan peningkatan kemuluran dan kekukuhan rasuk berbanding rasuk kawalan.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	Iii
	ACKNOWLEDGEMENT	Iv
	ABSTRACT	V
	TABLE OF CONTENTS	Vii
	LIST OF TABLES	X
	LIST OF FIGURES	Xi
	LIST OF APPENDICES	Xiii
1	**INTRODUCTION**	1
	1.1 Introduction	1
	1.2 Background of the Study	3
	1.3 Problem Statement	4
	1.4 Objectives of the Research	5
	1.5 Scope of the Research	5
	1.6 Significance of the Study	5
2	**LITERATURE REVIEW**	7
	2.1 Introduction	7
	2.2 History of Fibers Used in Composite	7
	2.3 Classification of Fibers	9
	2.4 Mechanical Properties	10
	2.4.1 Toughness	10

2.4.2 Flexural Strength 11

2.4.2.1 Measuring Flexural Strength 12

2.4.3 Compressive Strength 13

2.4.3.1 Compressive Strength of Concrete Cubes 14

2.5 Physical Properties 14

2.5.1 Shrinkage 14

2.5.2 Creep 15

2.6 Review of Research 15

2.7 Summary of Review 16

3 RESEARCH METHODOLOGY 18

3.1 Introduction 18

3.2 Experimental Work 18

3.3 Materials 20

3.3.1 Cement 20

3.3.2 Water 21

3.3.3 Aggregate 22

3.3.3.1 Fine Aggregate 22

3.3.3.2 Coarse Aggregate 23

3.3.4 Steel Fiber 23

3.3.5 Steel Reinforcement 24

3.3.6 Preparation of Reinforced Concrete Beam 25

3.3.6.1 Formwork 25

3.4 Concrete Mix Design 26

3.5 Fiber Volume Calculation 26

3.6 Sieving 28

3.7 Mixing 29

3.8 Slump Test According to BS 1881–102 29

3.9 Preparation of Samples 30

3.9.1 Optimum Percentage of Steel Fiber. 31

3.9.2 Hardened Properties of Concrete 31

3.9.3 Casting of Reinforced Concrete Beam 32

3.9.4 Curing Method 33

3.9.5 Density Test 34

3.9.6 Ultrasonic Pulse Velocity (UPV) Test 34

3.10 Testing of Samples 35

3.10.1 Compressive Strength 36

3.10.2 Splitting Tensile Strength 36

3.10.3 Flexural Strength 37

3.10.4 Shrinkage and Expansion Test 38

3.10.4.1 Shrinkage 38

3.10.4.2 Expansion 39

4 RESULT AND DISCUSSION 40

4.1 Introduction 40

4.2 Optimum Fiber Content 40

4.3 Workability of Fresh Concrete by Slump 42

4.4 Hardened Properties 42

4.4.1 Concrete Density 43

4.4.2 Ultrasonic Pulse Velocity (UPV) Test 44

4.4.3 Compressive Strength of Concrete 45

4.4.4 Flexural Strength of Concrete 48

4.4.5 Splitting Tensile Strength 50

4.4.6 Expansion and Shrinkage 52

4.5 Flexural Strength 53

4.5.1 Ultimate Load 53

4.5.2 Deflection 55

4.5.3 Cracking Behavior 56

5 CONCLUSIONS AND RECOMMENDATION 57

5.1 Conclusion 57

5.2 Recommendation

58

REFERENCES 59

Appendices A-B 62-65

LIST OF TABLES

TABLE NO	TITLE	PAGE
2.1	General properties of some fibers type.	10
3.1	Chemical and physical properties of OPC	20
3.2	Detail tests conducted for the optimum fiber content.	27
3.3	Mix proportion of concrete used	28
4.1	Optimum fiber percentage	41
4.2	Slump Result	42
4.3	Density of concrete cubes.	43
4.4	Ultrasonic pulse Velocity of concrete for cubes	44
4.5	Average compressive strength of cubic samples	46
4.6	Compressive strength	47
4.7	Average flexural strength	48
4.8	Flexural strength	49
4.9	Average splitting tensile strength	50
4.10	Splitting tensile strength	51
4.11	Represent the results of expansion and shrinkage (micro strain).	52
4.12	Flexural strength of beams and number of cracks at failure	54

LIST OF FIGURES

FIGURE NO	TITLE	PAGE
1.1	Types of steel fibers [2]	2
2.1	Fiber Classifications.	9
2.2	Beam under 3 point bending	12
2.3	Beam under four point bending	13
3.1	Flow chart for the experimental work.	19
3.2	Cement used for the experiment.	21
3.3	Water used for the experiment	21
3.4	Fine aggregate used for the experiment.	22
3.5	Coarse aggregate used in the experimental work	23
3.6	Hook end steel fiber used for the experiment	24
3.7	Reinforcement used for RC beam and SFRC beams	24
3.8	Steel cage reinforcement	25
3.9	Formwork for RC beams.	26
3.10	Mixing process of concrete with steel fiber	29
3.11	Nature of slump after addition of the fiber	30
3.12	Moulds used	31
3.13	Casting of beams	32
3.14	Schematic diagram of the Beam 3	32
3.15	Curing process	33
3.16	Measure Scale.	34
3.17	Instrument used for measuring UPV	35
3.18	Testing of cubes and its mode of failure	36
3.19	Splitting tensile testing	37

3.20	Failure mode prismatic sample	37
3.21	Concrete prism used for the shrinkage testing	38
3.22	Instrument used for measuring shrinkage/exp.	39
4.1	Optimum fiber	41
4.2	density of cubic sample	44
4.3	UPV for cubic samples	45
4.4	Compressive strength of SFRC and NC	47
4.5	Flexural strength	49
4.6	Splitting tensile strength test for cylinder	51
4.9	Control Beam	54
4.10	Beam 1 with 100%SF and 12 mm bar diameter	54
4.11	Beam 2 with 100% SF and 10 mm bar diameter	55
4.12	Beam 3 with 50 % SF and 50% NC with 12 mm bar diameter	55
4.13	Load vs mid-span deflection graph of RC and SFRC beam	56

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Mix Design	62
B	Fibre Volume Calculations:	64

CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete is a material that is being used for building construction for years, but it is weak in tension and brittle under stresses and impact loads. As a result, it cannot support higher load and stresses that usually take place on concrete beams and slabs resulting in cracks. Thus, it is necessary to look for ways of improving its properties. The addition of steel reinforcement significantly increases the tensile strength of the concrete in which it is in the form of continues reinforcing bars which is put in structures to withstand the imposed tensile and shear stresses. In order to produce concrete with homogenous tensile properties, the introduction of short fiber comes into play. Fiber reinforced concrete (FRC) is a concrete containing conventional materials which are cement, fine aggregate, coarse aggregate, water and admixture plus short fibers. The idea of using steel fibers was brought in to remedy the weakness of the concrete such as tensile strength, high shrinkage cracking and low ductility.

Steel fiber concrete has an excellent tensile strength, flexural strength, shock résistance, fatigue resistance, ductility, and crack arrest. They also improve the fresh properties of concrete by reducing bleeding of water. It can be applied in various engineering fields such as:

i. Industrial floor to reduce damage to abrasion and impact.
ii. In heavy machinery foundation to minimize damage due to vibration and dynamic load.
iii. It can be used for pavement, for highways and airport runways overlays to reduce both thickness and cracking.
iv. It could be commonly used for fabrication of precast products like pipes, beams, stair case, wall panels, roof panels, manhole covers, permanent formwork
v. It can also be used for tunnel lining and in concrete repair application.

The main reason for adding fiber to concrete matrix is to increase the toughness and tensile strength which improve the deformation characteristic of the composite. The composite properties such as crack resistance and an increase in toughness of FRC depends on the mechanical properties and bonding properties of fiber and matrix as well as the quantity and the fiber distribution within the matrix [1]. Figure 1.1 shows different types of steel fibers used in construction.

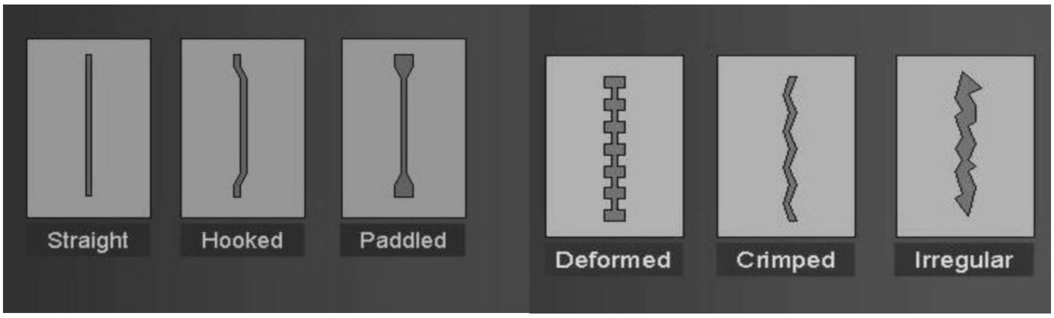

Figure 1.1 Types of steel fibers [2]

1.2 Background of the Study

In the past, attempts have been made to enhance the tensile properties of concrete members by using conventional reinforced steel bars and also by applying restraining techniques. Although both of these methods provide tensile strength to the concrete members, however, they do not increase the inherent tensile strength of the concrete itself [3]. Even though the concept of reinforced concrete (RC) has eliminated one of the major weaknesses of concrete, namely, inability to resist tensile forces, it still falls short of many more desirable properties like toughness, ductility, control of cracking and energy absorption. This is basically because the reinforcement component in RC is present in certain areas of the cross-section of the structural member. In order to achieve all the above mentioned properties it is essential to distribute the reinforcement uniformly throughout the cross-section. In fact, about 65% of the fibers produced worldwide are now employed in the construction of industrial floors, road pavements and slab-on-grade. Nevertheless, the most widely used fiber types are the steel which is applied to reduce the area of conventional reinforcement for the last 20years [4]. Steel fibers offer many advantages when used in reinforced concrete, particularly economic and technical advantages over conventional steel reinforced concrete, which include increasing the strength capacity and enhancing crack control in concrete. Steel fibers have a unique advantage over other type of fibers due to its high elastic-modulus, strong bonding with the cement paste and ease to deform which improves the anchorage in concrete.

The strength of the concrete also plays a measurable part in influencing the toughness characteristic. However, when the strength of the concrete matrix is higher, the load bearing capacity of the short-fiber reinforced concrete will experience a steeper and more sudden drop after the occurrence of the first crack. It was also reported that the addition of steel fibers increases the critical load required to reach the outset of macro crack significantly [5]. They further stated that 1% volume content of steel fiber could eventually equal to the usage of about 0.15% of flexural steel reinforcement.

If an increase in the tensile strength of the concrete is required, the use of large proportions of short-fibers are optional, to reduce the number of micro-cracks. On the other hand, for the control of macro-cracking, longer fibers should be adopted as they are more efficient in that aspect. The fibers should be added last to the fresh concrete in order to have a good mixture, care must be taken to ensure no clumps of fibers and the fibers are rapidly moved from the entry point to the mixer. Otherwise, they may be added onto the aggregate on the conveyor belt [6].

1.3 Problem Statement

Due to the weakness of concrete in tension, plain concrete develops plastic cracking, and plastic shrinkage even before loading. Under load the concrete is brittle in character which fails easily, making it unable to carry the load successfully. This problem needs to be addressed to ensure the structures safe under impact and loading condition. An alternative means have to be improvised in order to obtain material having the same behavior in both tension and compression to be able to cater for the safe functioning of structures. The use of short steel fibers has significant influence in improving the cracking characteristics [7]. It can also improve the structural behavior of a member, enhancing post cracking ductility and crack control. Studies also show that, steel fibers can reduce the amount of transverse shear reinforcement in beams while maintaining the required shear resistance. This research focus on studying the flexural behavior of beams reinforced with steel fiber under different stages for concrete grade M- 35.

1.4 Objectives of the Research

The main objectives of this research are as follows:

i. To determine the optimum percentage of steel fiber in concrete mix.
ii. To study the fresh and hardened properties of steel fiber reinforced concrete.
iii. To investigate the flexural performance of steel fiber reinforced concrete beams with different area of steel reinforcement.

1.5 Scope of the Research

The scope of this research focuses on the mechanical properties of steel fiber reinforced concrete (SFRC) and the application of the SFRC on beams to study its flexural performance under loads. The experimental program involves four beams, one RC beam as a control and the remaining three (3) beams having an optimum percentage of steel fiber (1%) with different cross-sectional area of steel reinforcement.

1.6 Significance of the Study

The main purpose of reinforcing the concrete is to improve the tensile strength of the concrete because concrete is good under compression but weak in tension. In this research, mechanical properties of SFRC were determined after which, the structural application of these steel fiber reinforced concrete on the beams were investigated. Beam 3 has 50% SFRC in tension zone and 50% NC in compression zone and this was compared with the beams having 100% SF.

REFERENCES

1. Amit. R. (2013), some studies on steel fiber. *International Journal of Emerging Technology and Advanced Engineering* Vol3. Pp 120.
2. Sreeja.M.D. (2013), Behavior of Steel Fiber Reinforced Concrete Beams Under Cyclic Loading. *International Journal of Mechanical and Civil Engineering (IOSR-JMCE)* Vol.6. pp 01-04.
3. Shetty M.S (2005), *Concrete Technology Theory and Practice*. Revised Edition S.Chand and Company LTD New Delhi 2.
4. Banthia, N. (1994), *Fiber Reinforced Concrete*, *American Concrete Institute*, Sp-142, pp.23.
5. Rossi P, Acker P, Mailer Y. (1987), Effect of Steel Fibers at Two Different Stages. *The Material and the Structures*. Vol.20, pp.34-39.
6. Naaman A. E. (2003), Engineered Steel Fibers with Optimal Properties for Reinforcement of Cement Composite. *Journal of Advance Concrete Technology* Vol. 1, No. 3, pp 241-252. (EM3), pp. 147-168.
7. Susetyo, J. (2009), *Fiber Reinforcement for Shrinkage Crack Control in Prestressed, Precast Segmental Bridges*. PhD dissertation, University of Toronto, Toronto, ON, Canada, 532
8. ACI 116 R (1980), *Material and General Properties of Concrete* in Manual of Concrete Practice part 1. American Concrete Institute.
9. NZS 3101-1(2006), *Concrete Structures Standard*. Prepared by Concrete Committee P3101 for Standard Council.
10. ACI Committee 544. (1986), *State-of-Art Report on Fiber Reinforced Concrete*, in ACI manual of concrete practice, part 5. American Concrete Institute, Michigan, USA.
11. Romualdi, J., and Baston, G. (1963) *Mechanics of Crack Arrest in Concrete*, Proceedings ASCE, pp 89.

12. Johnston, C.D. (1974) *Steel fiber reinforced mortar and concrete*. *A review of mechanical properties in fiber reinforced concrete.* ACI-Sp 44, American concrete.

13. Http://www.globalspec.com/learnmore/material_chemical-adhesive/composite-textiles-reinforcement/synthetic_fabrics-polymer.

14. Hodgkinson J.M. (2000), *Mechanical Testing of Advanced Fiber Composite*, Cambridge: Wood head publishing. Ltd. pp 132-133.

15. Elsaigh W.A masters theses. *A comparative evaluation of steel fiber reinforced concrete ground slabs*. Faculty of engineering, University of Pretoria. pp 2-18.

16. ACI 209R-*Prediction of Creep, Shrinkage and Temperature Effects in Concrete Structure.* Reported by ACI Committee 209.pp 147-168.

17. Mukesh S. (2011), Behavior of Reinforced Concrete Beam with Steel Fiber under Flexural Loading. *International Journal of Earth and Science Engineering*, Vol. 04, NO 06.SPL. pp 843-846.

18. Song P.S. and Hwang S. (2004), Mechanical Properties of High Strength Steel Fiber Reinforced Concrete. *Construction and Building Material*, pp 669-673.

19. Neves R.D and Fernandes J. C.O de Almedia (2005), Compressive Behavior of Steel Fiber Reinforced Concrete. *Structural Concrete.* Vol. No. 1, pp 1-5.

20. Shende A.M, Pande A.M. and Gulfam P.M. (2012), *Experimental study on steel fiber reinforced concrete for M-40 grade*. International referred Journal of Engineering and Science. Vol.1, issue 1 (September 2012), pp.043-048.

21. Alton. F (2006), *Effects of Steel Fiber Addition on Mechanical Properties of Concrete and RC Beams*. *Construction and Building Materials* Vol 21, pages: 654–661.

22. Mindess S., Young J.F. and Darwin .D. (2002), concrete 2nd Edition, Pearson Education, Inc., Upper Saddle River, NJ. USA.

23. MS29 (1995), *Specification for Aggregate from Natural Sources for Concrete*(first revision)

24. *Design of Normal Concrete Mixes*, Department of Environment (1988). United Kingdom's.

25. Standard Institution (1983), *Method for Determination of Slump*, London BS 1881: Part 102

26. Rancines, PG, and Pama RP. (1978), A Study of Bassage Fiber-Cement Composite as Low-cost Construction Materials. In*: Proceeding International Conference Materials for Developing Countries*. Bangkok. pp. 191–206.

27. ASTMC597 (2009), *Standard Test Method for Pulse Velocity through Concrete*, USA.

28. British Standard, BS 1881: Part 116: (1983), *Method for Determination of Compressive Strength of Concrete Cubes*.

29. ASTM C496. (1994), *Standard Test Method for Split Tensile Strength of Cylindrical Concrete Specimens.* Annual Book of ASTM Standards; 1994

30. ASTMC293/C293M, (2010), *Standard Test Method for Flexural Strength of Concrete* (Using Simple Beam with Center-Point Loading, USA.

31. ASTM-C157M (1999), *standard test method for the length change of hardened hydraulic cement mortar concrete.*

32. ASTM C 1038-14b.(1994), *Standard test method for expansion of hydraulic cement mortar bars* stored in water.

33. Hamid Pesaran Behbahanid, Behzad Nematollahi, Abdul Rahman Mohd.Sam, and Lai F.C. (2012) Flexural Behavior of Steel-Fiber-Added-Rc (Sfarc) Beams with C30 and C50 Classes of Concrete. *International Journal of Sustainable Construction Engineering & Technology*. Vol 3, Issue 1. pp 60.

34. Dixon, J. Mayfield. B. (1971) *Concrete Reinforced with Fibrous Wire*. *Journal of the concrete society, concrete*, pp 73-76.

35. Mandeep S.S, Inderpreet K. (2014), Experimental *study of Non-destructive test on steel fiber reinforced concrete.* Punjab Nanak Dev. Engineering College Ludhiana India. Pp 91-92.

36. ASTM C1018-97 (1997), *Standard Test Method for Flexural Toughness and First Crack Strength of Fiber- reinforced concrete* (using third point loading). ASTM standard.