Sisal Fiber as Steel Bar Replacement of Lightweight Concrete under Flexural Loading

by Suryawan Murtiadi

Applied Mechanics and Materials
ISSN: 1662-7482, Vol. 845, pp 202-207
doi:10.4028/www.scientific.net/AMM.845.202

Submitted: 2015-07-29
Revised: 2015-10-17
Accepted: 2015-10-17
Online: 2016-07-25

Sisal Fiber as Steel Bar Replacement of Lightweight Concrete under Flexural Loading

MURTIADI Suryawan[1, a*] and AKMALUDDIN[1,b]

[1] Department of Civil Engineering, Mataram University, Indonesia

[a*]s.murtiadi@unram.ac.id, [b]akmaluddin@unram.ac.id

Keywords: Sisal, reinforcement, lightweight concrete, beam, flexure

Abstract. Low cost building material is very intending in developing countries. The purpose of this study is to identify the prospect of sisal fiber as a replacement of steel bar reinforcement for structural element. Behavior of lightweight concrete beam was examined to discover the performing sisal reinforcement.
Four variation beam specimens of 100 x 150 mm with 1.5 m effective span were tested under flexural loading. The specimens' variation consisted of one controlling steel reinforcement and three variations of sisal fiber where every variation was represented in three samples. Flexural static loading of simple supported beam were applied and vertical deflections of the bottom mid-span were recorded throughout the test.
Test results indicated that the crack moment experiments were higher than the crack moment calculations. The valued were 1.44, 1.52, 2.72, and 3.32 for sisal fiber reinforcement of B-LF, B-MF, B-HF, and for steel reinforcement of B-LS, respectively. Observation results also indicated that the moment resistant capacities of the specimens were twice higher compare to the calculated moment capacity. However, the lowest sisal reinforcement (B-LF) has only about 10% different service moment compare to the steel reinforcement (B-LS) where they both have equal $\rho = 1.206$ %. This indicate that the use of sisal fiber have considered as insignificant different service moment capacity to the steel reinforcement.

Introduction

Pumice and sisal plant available in the tropical countries with their massive obtainability. These nature materials can be considered in polymer composites materials with their lightweight and specifics strength. The purpose of this study is to identify the prospect of sisal fiber as a replacement of steel bar reinforcement for simple structural element. Behavior of sisal fiber reinforcement of lightweight concrete beam with pumice as coarse aggregate was examined under flexural loading. The variations of sisal reinforcement were determined in order to optimize its performance.

The use of pumice as coarse aggregate of lightweight concrete has been intensively studied by researchers. The reports show that the used of this material can be satisfactorily applied for medium structural element. Precast element for frame system has also been introduced with and without infill wall [1,2]. The other advantage of using lightweight concrete is to resist high temperature and fire resistance [3].

In recent years the use of plant fibers in polymer composite materials has been widely explored. Sustainable and low price material are the main reason using these materials in the construction [4,5]. Tolerable applications of natural fiber in the construction industry have also been reported with reasonable strength, stiffness and buckling resistance. The advantage of the plant fibers and its application into lightweight concrete is the answer of economic housing construction problem in developing countries [6,7].

Experimental Method

Materials. Mix design of lightweight concrete with pumice as coarse aggregate was obtained in the laboratory. For 1 m^3 concrete mixture, the mix proportion of cement, sand, water, and pumice was 408 kg, 319 kg, 183 kg and 515.5 kg, respectively. This mix proportion produced concrete compressive strength of 17 MPa.

In order to prepare sisal fibers for bar reinforcement, natural sisal leaves were soaked into water for two days. The fiber were separated from the leaves and dried in the sun for one day then to be formed into 8 mm diameter ropes. Polyester resin BQTN type 157 was coated to make the ropes stiff and rigid. Tensile test was carried out to obtain the tensile strength of the rope. Fig. 1 shows the sisal specimen for tensile test and the rigid sisal fiber ready to be used for beam reinforcement. The tensile strength of 30 MPa and density of 336.60 kg/m^3 was obtained from the test results.

Fig. 1 Sisal Specimen under Tensile Test (left) and Bars Reinforcement of Sisal Fibres (right)

Test Specimens. The experimental investigation was carried out at Structural and Material Laboratory of Mataram University. The specimens' variation consisted of one controlling steel reinforcement and three variations of sisal fiber where every variation was represented in three samples. In total, twelve beams have been tested in this study. Steel stirrups Ø8-150 mm were utilized as shear reinforcement and links. Prior to the test, three standard cylinders of 150 x 300 mm concrete mixture were tested to obtain compressive strength and modulus elasticity of the lightweight concrete.

(a) (b) (c)

Fig.2 Lightweight Concrete Beam Preparation

Fig 2 shows the preparation of concrete beam specimens. The process started with forming the cage of reinforcement where longitudinal sisal bars enclosed by steel stirrups Fig.2(a). The reinforcement cage then fixed into the formwork Fig.2(b) follow by casting and compacting the concrete around the reinforcement Fig.2(c). Overall twelve beams were casting in this study with 1.7 m length to create effective span L of 1.5 m. Detail of the beam specimen is shown in the following Table 1 with the beam code, number of samples and cross-section dimension.

Table 1. Detail of Beam Specimens

Code	Number of Sample	Dimension (mm)		
		b	*h*	*d*
B-LF	3	100	150	125
B-MF	3	100	150	125
B-HF	3	100	150	117
B-LS	3	100	150	125

Coding of the above Table can be explained as follows:

- B-LF : **B**eam with **L**ow **F**iber reinforcement
- B-MF : **B**eam with **M**edium **F**iber reinforcement
- B-HF : **B**eam with **H**igh **F**iber reinforcement
- B-LS : **B**eam with **L**ow **S**teel reinforcement

Where: b = width, h = height and d = effective height of the beam.

Test Setup and Instrumentation. Flexural testing was setup with placing the test specimen as a simple supported beam as seen in Fig. 3. Load cell was placed at the mid-span and distributed the load through two symmetric points steel profiles with the distance of 1/3 L. Hydraulics jack with 50 ton capacity connected to the load cell was operated as a source of loading. LVDT was mounted in the mid-span to measure vertical deflections during the loading. Cracks were monitored at every increasing load and the mechanism of failure was scrutinized.

Fig.3 Flexural Testing *Set-up* of the Beam

Results and Discussions

Load-Deflection under Flexural Loading. LVDT in the bottom mid-span of the beam clearly recorded the vertical deflection when the loading start working. Flexural loading will develop a crack perpendicular to the axis starting from the bottom of mid-span. Increasing the load will increase the deflection proportionally followed by deeper crack and even generated new cracks spread at the bottom of the beam. Further loading will generate more cracks until the load bearing capacity of the beam was exceeded and the failure was occurred. The load-deflection diagrams of B-LF, B-MF, B-HF, and B-LS are presented in Figs. 4, 5, 6, and 7, respectively.

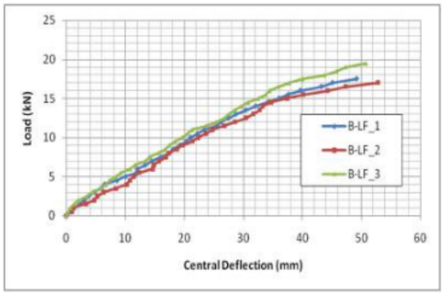

Fig. 4 Load-Deflection of B-LF

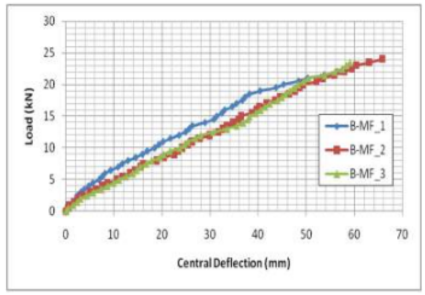

Fig. 5 Load-Deflection of B-MF

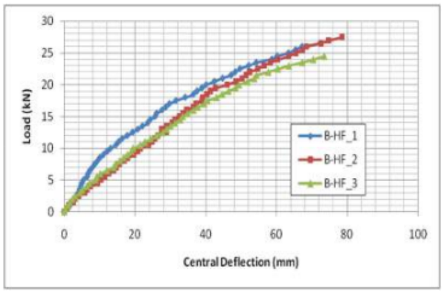

Fig. 6 Load-Deflection of B-HF

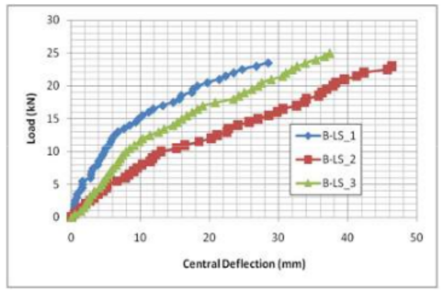

Fig. 7 Load-Deflection of B-LS

Crack Moment (Mcr). Table 2 gives the comparison of the crack moment between the test results, Mcr(exp), and the theoretical calculation, Mcr(th). It can be seen from the table that the tests valued were 1.44, 1.52, and 2.72 higher for sisal fiber reinforcement of B-LF, B-MF and B-HF, respectively. Whilst for steel reinforcement of B-LS the valued were 3.32 higher. The value experimental results of the crack moment were higher compare to the theoretical crack moment. It can be understood since the theoretical calculation of crack moments were based on the concrete strength alone without taking into account the presence of the reinforcement.

Table 2. Comparison of the Crack Moment

Beam	ρ (%)	$P_{cr(th)}$ (kN)	$M_{cr(th)}$ (kNm)	$P_{cr(exp)}$ (kN)	$M_{cr(exp)}$ (kNm)	Ratio
B-LF	1.206	3.325	0.831	4.800	1.200	1.444
B-MF	2.412	3.300	0.825	5.000	1.250	1.515
B-HF	5.153	3.300	0.825	9.000	2.250	2.727
B-LS	1.206	3.308	0.827	11.000	2.750	3.325

Ultimate Moment (Mu). Ultimate moment can be defined as moment resistance capacity of the beam which can be obtained from the flexural testing. Shown in Table 3, experimental result all of specimens have the moment resistance capacity more than twice higher than its theoretical analysis. It can be obviously seen from the table that the value of B-HF was higher than the steel reinforcement beam of B-LS. This indicated that the use of sisal fiber can be identified has substantial prospect as a replacement of steel bar reinforcement.

Table 3. Comparison of Ultimate Moment

Beam	ρ (%)	Mu(th) kNm	Mu(exp) kNm	Ratio
B-LF	1.206	2.208	4.503	2.039
B-MF	2.412	2.464	5.791	2.350
B-HF	5.153	2.960	6.546	2.211
B-LS	1.206	2.205	5.815	2.637

Service Moment (Ms). Service moment capacity is defined as the capacity of the beam to withstand the loading with the boundary condition of maximum deflection and crack width. In this experimental result, the service moment capacities can be derived from the corresponding allowable deflection ($\delta_S = L/240$) on the load-deflection curves. The results of the service moment capacities are presented in Table 4.

Table 4. Service Moment Capacity

Beam	ρ (%)	δ_S (mm)	Ms (kNm)	Normalized to B-LF
B-LF	1.206	6.250	4.250	1.000
B-MF	2.412	6.250	4.800	1.129
B-HF	5.153	6.250	4.850	1.141
B-LS	1.206	6.250	4.850	1.141

The table shows that almost all of the beams have similar service moment capacity. The lowest sisal reinforcement (B-LF) has only about 10% different service moment compare to the steel reinforcement (B-LS) where they both have equal $\rho = 1.206$ %. This indicate that the use of sisal fiber have considered as insignificant different service moment capacity to the steel reinforcement. Therefore, the use of sisal fiber can be identified has substantial prospect as a replacement of steel bar reinforcement for simple and medium structural element.

Summary

The following summaries can be drawn based on the experimental results:

- Test results indicated that value of the first crack moment experiments were 1.44, 1.52, 2.72, and 3.32 higher for sisal fiber reinforcement of B-LF, B-MF, B-HF, and steel reinforcement of B-LS, respectively.
- The moment resistant capacities of the specimens were twice higher compare to the calculated moment capacity.
- The lowest sisal reinforcement (B-LF) has only about 10% different service moment compare to the steel reinforcement (B-LS) where they both have equal $\rho = 1.206$ %. This indicate that the use of sisal fiber have considered as insignificant different service moment capacity to the steel reinforcement.
- The use of sisal fiber is identified has substantial prospect as a replacement of steel bar reinforcement for simple and medium structural element.

Acknowledgment

This research has been funded by the Directorate General of Higher Education, Ministry of Education and Culture, the Government of Republic Indonesia under the scheme of "National Strategic" research grant. The authors like to express sincere gratitude for the funding.

References

[1] Akmaluddin: *Effect of Tensile Reinforcement Ratio on the Effective Moment of Inertia of Reinforced Lightweight Concrete Beams for Short Term Deflection Calculation*, ITB J. Eng. Sci., pp. 209-226 (2011)

[2] A. Akmaluddin, R.S. Saftaningtyas, S. Rawiana, and Z. Gazalba: *Hybrid Reinforced Concrete Frame Building With Pumice Brick Masonry Infill Under Statics Lateral Loading*, International Journal of Engineering and Technology, Vol. 2 No. 8, pp. 1482-1491, IJET Publications UK (2012)

[3] S. Murtiadi: *Review of Indonesian Standard for Concrete Building Subjected to Fire*, Procedia Engineering, Vol. 54, pp. 668-674, Elsevier (2013)

[4] A. Bismarck, Y. Baltazar, and K. Sarlkakis: *Green Composites as Panacea*, Socio-Economic Aspects of Green Materials, Vol.8, pp. 445-463 (2006)

[5] M.C. Khoatane, O.C. Vorster, and E.R. Sadiku: *Hemp Fiber Reinforced Pentene/Polypropylene Copolymer: The Effect of Fiber loading on the Mechanical and Thermal Characteristics of the Composites*, Journal of Reinforced Plastics Composites, Vol. 27, 1533p (2008)

[6] A. Akmaluddin, and S. Murtiadi: *Hybrid Precast Concrete Column and Sandwich Beam under Static Loading*, Procedia Engineering, Vol. 54, pp. 268-298, Elsevier (2013)

[7] S. Murtiadi, A. Akmaluddin, Z. Gazalba, and S. Sinarep: *Sandwich Concrete Panel Reinforced with Sisal Fiber Mesh for Application in Wall Construction System,* Proceeding of the 1st International Conference on Infrastructure Development, UMS Surakarta, pp.308-314 (2013)

Sisal Fiber as Steel Bar Replacement of Lightweight Concrete under Flexural Loading

ORIGINALITY REPORT

5%	3%	3%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universitas Mataram Student Paper	5%

Exclude quotes	On	Exclude matches	< 3%
Exclude bibliography	On		