Structural Performance Evaluation of *Landolphia buchananii* Shear Reinforced Concrete Beams

M. K. Ketter[a], E. Nsabimana[a]

[a]Department of civil engineering, Dedan Kimathi University of Technology, Kenya

Abstract: ***This study aims to evaluate the performance of Landolphia buchananii shear reinforced concrete beams to establish the potential of Landolphia buchananii as a shear reinforcement of concrete beams. Tensile strength test on Landolphia buchananii was performed and reinforced concrete beam test was done. The performance of Landolphia buchananii shear reinforced concrete beam was compared to that of steel shear reinforced concrete beam. Varying size/area of shear reinforcement of Landolphia buchananii was used for beam specimen made of concrete of average compressive strength of 20.8 N/mm^2. The results showed that the failure loads increased with increase in area/size of shear reinforcement. Tensile strength of Landolphia buchananii was found to be 65 percent lower than that of conventional mild steel. The study showed that Landolphia buchananii can be used as shear reinforcement in concrete beams and can be used as a substitute of steel under low loading regimes.***

Keywords: *Landolphia buchananii*, reinforced concrete beam, shear link, bending, crack, deflection

1. Introduction

Steel is majorly used as a reinforcement in concreted due it its high tensile strength which compliments concrete low tensile strength. However, use of steel in construction has its own limitations; it is costly, energy consuming and carbon dioxide (CO2) emitting during manufacturing process [1]. These limitations have led to increasing interest in the possible use of alternative locally available materials for the reinforcement of concrete. Research has been done on several vegetable fibres as reinforcements of concrete. Bamboo [1-7], mangrove [8-9], babadua [10], rattan cane [11-12] and palmyrah [13] has been studied as a possible reinforcement of concrete to evaluate its performances as concrete reinforcement material.

This study focuses on *Landolphiabuchananii* stem as one of the vegetable fibres. The study will focus on the structural capabilities of *Landolphiabuchananii* as shear reinforcement in concrete. *Landolphiabuchananii* is a flexible forest liana and sprawling shrubs with latex filled stems, jasmine-scented flowers and fruits growing up to forty meters tall and twenty centimetres in diameter [14]. It grows in Eastern Africa, Central Africa and parts Western Africa [15].

Experimental investigation and evaluation of the use of *Landolphiabuchananii* stem as shear reinforcement material in concretes has been presented in this paper. The experimental program, tests results and discussion and conclusion has been dealt with in this paper.

2. Materials, Sample Preparation, Mix Design and Concrete Beam Preparations

2.1 Materials

a) Cement: Local Portland Pozzolona cement manufactured to Standard Specification KS EAS 18-1: 2001 and classified as CEM IV/B-P 32.5N Portland Pozzolana cement.
b) Coarse aggregate: Coarse aggregate of maximum size of 20mm as specified in accordance to BS 882[16].
c) Fine aggregate/Natural sand: Normal River sand as specified in accordance to BS 882[16].
d) *Landolphia buchananii* stems: Obtained from Nandi forest in western Kenya. The diameters of the stems varied from 6 mm to 13mm.
e) High yield twisted and mild steel bars: 12mm and 6mm diameter respectively as specified in accordance to BS 8110 [17].

2.2 Sample preparation

2.2.1 *Landolphiabuchananii* stems

Stems of uniform cross-sections along the length were selected and their bark removed. For each stem, the diameters were measured at three positions and then averaged; the positions were at the two ends and the middle of the stems. For tensile and shear tests, the test specimens were prepared in accordance to BS 373 [18].

2.3 Concrete mix preparation

Concrete standard nominal mix proportion of 1:2:4 by volume which is expected to yield a target compressive strength of 20N/mm^2 at the age of 28 days was adopted from British Standard BS 8500[19]. To maintain workability and avoid excess water which can cause the swelling of the stem, the slump value was maintained at 30-40 mm.

2.4 Reinforced concrete beam specimens

Beams with varying areas of shear reinforcement were used. There were five beams each with longitudinal reinforcement of 12 mm diameter high yield twisted steel, two at both top and bottom. One of the five beams was purely reinforced with steel to act as a control while the rest were reinforced with *Landolphiabuchananii*as shear reinforcements. Shear links spacing was maintained at 200 mm centre to centre for all the beams. Beams were of 1100 mm length, 150 mm width and 250 mm depth. The diameters /size of shear reinforcement was 6mm, 8mm, 2x10mm and 2x13mm for *Landolphiabuchananii* reinforced and 6 mm for steel reinforced.

Concrete was compacted with poker vibrator and a concrete cover of 20 mm to links was maintained. Specimens were then cured for 28 days in wet conditions. Concrete cubes of 150 x 150 x150 mm were cast alongside the beams and cured in a water tank for 28 days. Figure 1 show steel fixed with *Landolphiabuchananii* as shear links.

The following notations have been use throughout this paper for ease identification throughout this paper:

L.B.1x6: Beam with 2Y12 top and bottom and *L. buchananii* shear links of diameter of 6mm with spacing of 200mm.
L.B.1x8: Beam with 2Y12 top and bottom and *L. buchananii* shearlinks of diameter of 8mm with spacing of 200mm.
L.B.2x10: Beam with 2Y12 top and bottom and *L. buchananii* double shear links of diameter of 10mmwith spacing of 200mm.
L.B.2x13: Beam with 2Y12 top and bottom and *L. buchananii* double shear links of diameter of 13mmwith spacing of 200mm.
Steel 1x6: 2Y12 top, 2Y12 bottom, R6 links spacing 200mm.

Figure 1: Fixed *L.buchanananii*as shear reinforcements

3. Experimental Programme

The experimental programme entailed determination of compressive strength of a concrete cube, tensile strength of *L. buchananii*stemand shear, bending strength, deflection and failure mode of *L.buchananii* and steel shear reinforced concrete beams.

3.1 Tensile strength of *Landolphiabuchananii*

Tensile strength was determined in accordance to BS 373-1957.Tensile test method of tension parallel to the fibers was performed. Load was applied on 2 cm face to the test pieces at a constant head speed of 1.27mm/min. The specimen was shaped as shown in Figure 2 to allow failure at gauge section.

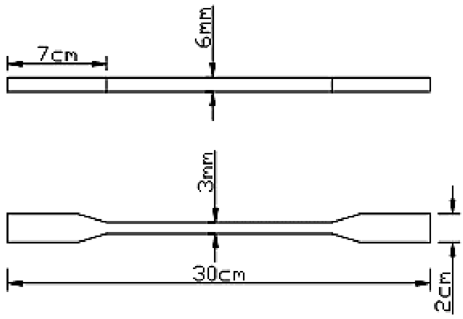

Figure 2: Test piece for tensile strength test

3.2 Beam Test and Cube Compressive Test

Beam test and compressive test was conducted after 28 days of curing. The test conducted was based on three point loading arrangement with span between the supports centres being 900mm as shown in Figure 3. Displacement transducer was used to measure deflection at mid-span. Loading was applied at mid-span of the beam gradually to failure while recording load and deflection at intervals. First crack load and crack type was also observed.

Compressive test was performed on concrete cubes specimen after 28 days and their respective strengths determined.

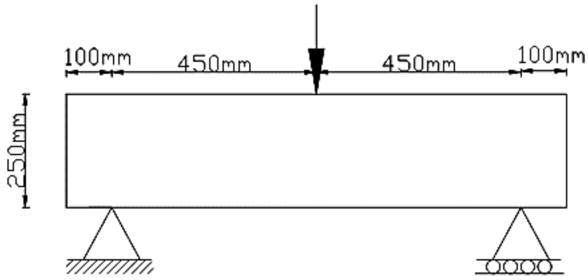

Figure 3: Bending test setup

4. Test Results and Discussion

4.1 Tensile strength of *Landolphiabuchananii*

The average tensile strength for Landolphia buchananii stem was 87.2 N/mm^2 which is around 35% that of conventional mild strength steel usually used as shear reinforcement. From Figure 4 it can be seen that failure occurred near the portion prepared for grip.

Figure 4: Mode of failure of tensile test samples

4.2 Compressive strength

Mean compressive strength of concrete cubes at the age of 28 days was 20.8 N/mm^2 which was higher than the target strength of 20N/mm^2. The mean slump value was 34mm which was between 30-40mm.

4.3 Beam Test

The findings in Fig.5 show the load-deflection curves for steel and *Landolphiabuchananii* reinforced concrete. All the curves generally exhibit non-linearity for all the loads to failure. From Table 1, *Landolphiabuchananii* reinforced concrete beams failed between 58 kN and 79.8 kN while that of steel reinforced beam failed at 81.3 kN with failure load coincide with the last point of the curves. Yield deflection for L.B.1x6, L.B.1x8, L.B.2x10, L.B.2x13 and steel 1x6 was 2.9, 0.69, 5.9, 3.36 and 8.1 mm while their first crack loads deflection was 1.35, 0.49, 0.25, 1.98 and 0.9mm respectively. Failure loads for *Landolphiabuchananii* reinforced concrete beams increased with increase in the area of shear reinforcement of *Landolphiabuchananii*.

From Table 1, it can be seen that the bending stress and shear stress of *Landolphiabuchananii* reinforced concrete beams increased with increase in area of shear reinforcement of *Landolphiabuchananii*. It can be seen that the bending stress and shear stress of the *Landolphiabuchananii* beam with the largest area of shear reinforcement (L.B. 2x13) was around 94 % that of steel reinforced beam (steel 1x6) as shown in Figure 6 and 7.

In accordance to BS 8110 beams are considered to have failed when deflection exceeds the ratio span/360 which was 2.5 mm. Load at this deflection was 52 kN, 65 kN, 32, kN and 65 kN for L.B.1x6, steel 1x6, L.B.2x10 and L.B.2x13 respectively. L.B.1x8 load reached maximum before the deflection limit. It can be seen that the load at this deflection is same for steel1x6 and L.B.2x13.

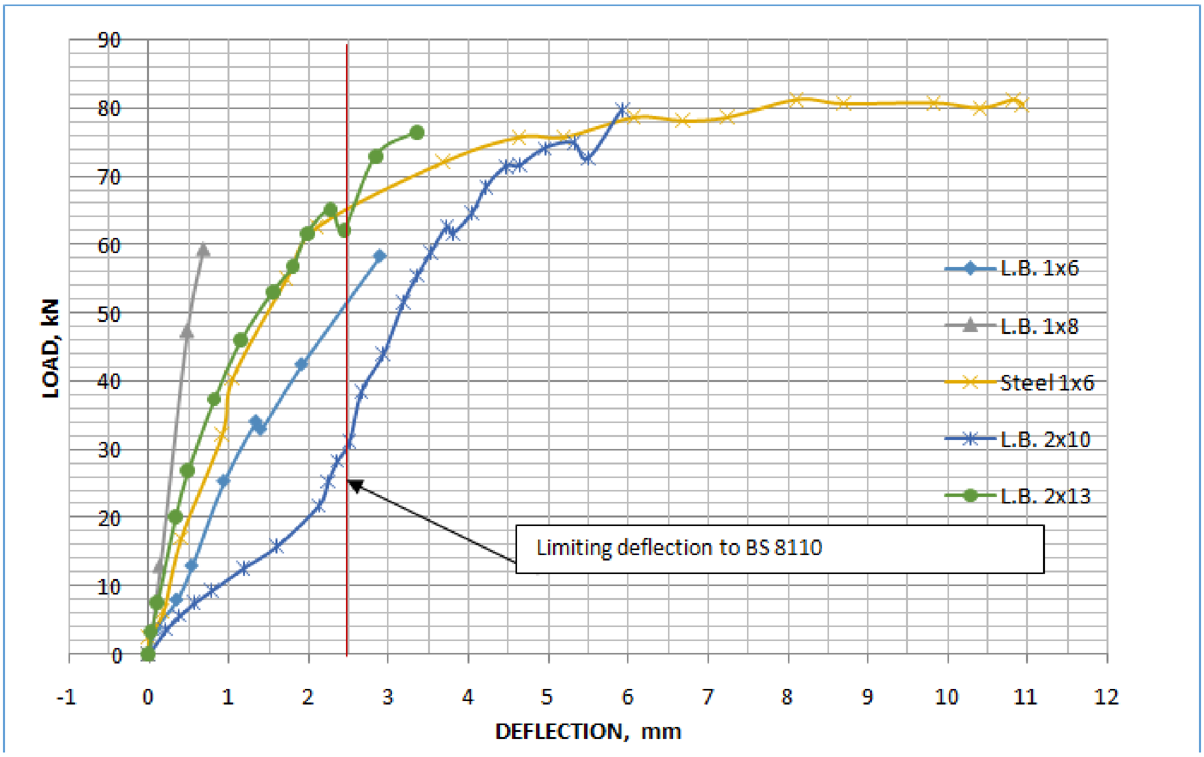

Figure 5: Load-deflection curves for shear reinforced beams.

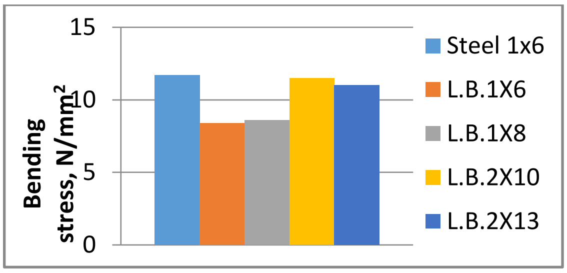

Figure 6: Comparison of bending strengths of shear reinforced concrete beams

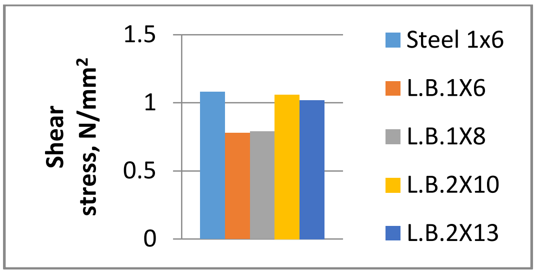

Figure 7: Comparison of shear strengths of shear reinforced concrete beams

4.4 Failure Modes

The results presented in Table 1 are first crack loads, ultimate loads, first crack load deflections, second crack load deflections, shear stresses and bending stresses of the reinforced concrete beams at the age of 28 days. From Table 1, it can be seen that the load carrying capacity of the beam depended on the area of shear reinforcement i.e. the larger the area of shear reinforcement the larger the load carrying capacity.

Shear failure is noted in the entire *Landolphiabuchananii* reinforced concrete beam with crack occurring from the bottom side of the beam near the support diagonally to the point of loading. From load-deflection curves (Figure 5) and the failure pattern *L.buchananii* reinforced beams (Figure 9, 11, 13 and 15) as compared to that of the steel reinforced beam (Figure 17), it can be noted that the beams failed in shear. When the region of failure crack was examined (Figure 8, 10, 12 and 14), the *L.buchananii* stem was unbroken, this can suggest that there was a poor bond between *L.buchananii* and concrete which led to beam failing in bonding or that the reinforcement was flexible enough to not to break. The flexibility of *Landolphiabuchananii* shear reinforcements can be attributed to low modulus of elasticity.

Table 1: Beam test results for *L. buchananii*as a shear reinforcement.

L. buchananii as shear reinforcement							
Beams	**Deflection, mm**		**Load, kN**		**Stresses**		
	1st crack	**Max.**	**1st crack**	**Max.**	**Bending stress, N/mm²**	**Shear stress, N/mm²**	**Mode of failure**
Steel 1x6	0.9	8.11	32.2	81.3	11.7	1.08	Shear +flexure
L.B.1x6	1.35	2.9	34.1	58.4	8.4	0.78	Shear
L.B.1x8	0.15	0.69	47.5	59.5	8.6	0.79	Shear
L.B.2x10	2.94	3.9	31.2	79.8	11.5	1.06	Shear
L.B.2x13	1.98	3.36	61.3	76.5	11.0	1.02	Shear

Figure 8: Unbroken shear reinforcement for L.B.1x6 beam

Fig.10: Unbroken shear reinforcement for L.B.1x8 beam

Figure 9: Failure pattern of L.B.1x6 beam

Figure 11: Failure pattern of L.B.1x8 beam

Figure 12: Unbroken shear reinforcement for L.B.2x10 beam

Figure 13: Failure pattern of L.B.2x10 beam

Figure 14: Unbroken shear reinforcement for L.B.2x13 beam

Figure 15: Failure pattern of L.B.2x13 beam

Figure 16: Snapped shear reinforcement for steel 1x6 beam

.

Figure 17: Failure pattern of Steel1x6 beam

5. Conclusion

From this study of *Landolphiabuchananii* shear reinforced concrete beams, it can be seen that *Landolphiabuchananii* improves the load carrying capacity of the beams when used as shear reinforcement. The following conclusions can be drawn from the study:

a. Failure loads of the beams increased with increase in the size/area of shear reinforcement of *Landolphiabuchananii*. Failure load of the beam with smallest and largest area of shear reinforcement being 58 kN and 79.8 kN respectively.
b. Bending stress and shear stress of *Landolphiabuchananii* reinforced concrete beam increased with increase in area of shear reinforcement of *Landolphiabuchananii*. Bending stress and shear stress of the beam with the largest area of shear reinforcement of *L. buchananii* (L.B. 2x13) was around 94 % that of steel reinforced beam (steel 1x6).
c. The tensile strength of *Landolphiabuchananii* was lower than that of conventional mild steel by about 65%.
d. Mode of failure of *Landolphiabuchananii* shear reinforced concrete beams was due to shear and failure due to bonding between concrete and *L. buchananii.*
e. There is need to investigate the bonding behavior of *L. buchananii*when used as reinforcement of concrete

Reference

[1] Harish Sakaray, N.V. Vamsi Krishna Togati and I.V.Ramana Reddy, "Investigation on properties of bamboo as a reinforcing material in concrete", International Journal of Engineering Research and application (IJERA). Vol.2, ISS01 pp. 077-083, 2012.
[2] Adom-Asamoah Mark, Afrifa Owusu Russell, "A comparative study of Bamboo reinforced concrete beams using different stirrup materials for rural construction", International Journal of Civil and Structural Engineering. ISSN 0976 – 4399 .Volume 2, No 1, 2011.
[3] Amada, S. and Untao, S. (2001), “Fracture Properties of Bamboo”, Composites Part B, Vol. 32, pp 451-459.
[4] Ghavami, K., "Bamboo as reinforcement in Structural Concrete Elements", Elsevier Cement Concrete Composites 1995; 17(4):281–8, 1995.
[5] M.M. Rahman, M.H. Rashid, M.A. Hossain, M.T. Hasan and M.K. Hasan, "Performance evaluation of bamboo reinforced concrete beam", International journal of engineering and technology, (IJET-IJENS) Vol. 11, No.21, 2011.
[6] Tara Sen, H. N. Jagannatha Reddy, “Application of Sisal, Bamboo, Coir and Jute Natural Composites in Structural Up-gradation", International Journal of Innovation, Management and Technology, Vol. 2, No. 3, 2011.
[7] M.D. Ahsan Sabbir, S.M. Ashfaqul Hol, and Saiada Fuadi Farcy, "Determination of Tensile property of Bamboo for using as a potential reinforcement in the concret", International Journal of Civil and Environmental Engineer Vol. 11 No: 05, 2011.
[8] Manguriu, G., Oyawa, W., and Abuodha, S., "Physical and mechanical properties of mangrove from Kilifi in

Kenya", Global Engineers& Technologists Review, 3, 1-5, 2013.
[9] Kallemana Aze Kerte, Timothy Nyomboi, Walter Oyawa, "Structural performance of mangrove reinforced concrete beams", International Journal of Engineering Sciences & emerging Technologies. Vol. 7 No 1, 2014.
[10] Charles K. Kankam, Brigitte Odum-Ewuakye, "Structural behaviour of babadua reinforced concrete beams", Elsevier construction and building materials, 13: 187-107, 1999.
[11] Obilade I.O., Olutoge F.A., "Flexural characteristics of rattan cane reinforced concrete beams". The International Journal of Engineering and Science (IJES), 3(6): 38-42, 2014.
[12] Akinyele J. O., OlutugeF. A., "Properties of Rattan Cane Reinforced Concrete Façade Subjected to Axial Loading", Journal of Civil Engineering and Architecture, 5(11): 1048-1052, 2011.
[13] Baskaran K., Mallikarachchi H.E., Jayasekara M.J.L.M., and Madushanka G.A.T., "Feasibility of using palmyrah strips as reinforcing material in cost effective houses", Hindawi Publishing Corporation Journal of Construction Engineering, Article ID 589646, 2014
[14] National research council of the natural Academies (NRCNA). "Lost crops inAfrica Volume III: Fruits", The National Academies press Washington D.C.2008.
[15] Persoon J.G.M., Van Dilts F.J.H., Kuijpers R.P., Leeuwenberg A.J.M and Vonk G.J.A., "The African species of *Landolphia P. Beauv*. Series of revisions of Apocynaceae" XXXIV. First edition. Kluwer Academic Publishers, Dordrecht/ Boston/ London.1992.
[16] BS 882,"Specification for aggregates from natural sources for concrete". UK, London, 1992.
[17] BS 8110-1, "Code of practice for design and construction". UK, London, 1997.
[18] BS 373, "Methods of testing small clear specimen of timber", UK. London, 1957.
[19] BS 8500, "Method of specifying and guidance for the specifier", UK, London, 2006