Development of an Eco-Friendly Bamboo Bicycle.

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ABSTRACT

Transportation is vital to the survival of a majority of Africans especially as it relates to transportation of farm produce and also to commutes to and from work. The conventional means of transportation are either expensive or not designed for rural Africa. In response to this, a bamboo bicycle was designed and developed to solve the immediate transportation needs of rural farmers using Nigeria as a case study. The frame of the bicycle was made form eco-friendly materials (bamboo), weighs 2.6 pounds (compared to a steel frame which weighs 3 -3.5 pounds), and has a tensile strength of about 40kN/cm^2 compared with steel that can resist 37kN/cm^2. The durability is currently being tested. The test unit was built in November, 2009, and so far, volunteer testers are pleased with it in terms of comfort and utility.

(Keywords: bamboo, bicycle, eco-friendly, transportation, low-income, ergonomic)

INTRODUCTION

In recent years the need for an eco-friendly means of transportation that is affordable to all sectors of developing countries has become more apparent. The cost of importation of materials (carbon fiber reinforced plastic, etc.) has been identified as the major reason for the increase in cost of purchasing a bicycle. In Nigeria, for instance, a utility bicycle cost about N15, 000 (about $100 US). In order to optimize cost, the need to source materials locally has been identify as an important factor. This works therefore focuses on the design and development of a bamboo bicycle for developing countries like Nigeria.

Bicycles are in great demand as a major labor savings device in transporting water, people, food and other items in rural Nigeria. The designed and developed Bamboo bicycles described in this paper cost less than other imported steel bicycles in Nigeria since the raw materials (Bamboo) is locally available in abundance and does not require electricity or a large investment in equipment. Bamboo is easy to grow and can be cultivated in dry areas with minimal irrigation. Bamboo bicycles also require a significant amount of labor to produce, providing skilled employment and an apprenticeship model that helps youths to find job opportunities.

METHODOLOGY

Materials Selection

Bamboo is a natural composite material longitudinally reinforced by strong fibers. It was chosen for this work because it is cheap and fast growing as well as easy to possess the under listed properties with the mechanical properties shown in Table 1.

(a) Lightness: In wood, the strongest fibers are packed in the centre of the trunk, however in bamboo, the stems are full of cavities and the strongest fibers are distributed most densely in the outer surface region.

(b) Stiffness: As a consequence the most stable fiber structures in bamboo are most dense in regions of greatest longitudinal stress. Wood bends relatively easily but bamboo does not.

(c) Strength: Extremely strong wood fibers can resist up to 5kN/cm2 and steel can resist at most 37kN/cm2 whereas the outer fibers of slim bamboo tubes have tensile strengths of up to 40kN/cm2.

Bamboo is therefore an ideal material for bicycle construction where stiffness and strength to weight ratios are important and it is the closest to Carbon fiber reinforced plastic.

Table 1: Mechanical Properties of Bamboo (CSE EduPack Granta Software; 2007)

S/N	Mechanical Properties	Value (KN/Cm^2)
i.	Elastic modulus	2000
ii.	Compressive strength	6.2-9.3
iii.	Tension strength	14.8-38.4
iv.	Bending strength	7.6-27.6
v.	Shearing strength	2.0
vi.	Density	$640kg/m^3$
vii.	Poisson Ratio	0.3

Other Materials

I. Epoxy and Resin
II. Unidirectional Carbon Fiber
III. Graphite stock for the Dropout
IV. Hacksaw for cutting the Bamboo into appropriate sizes

Methods

The following are the abridged steps in developing the Bamboo bicycle:

Step 1: Outsourcing the Intricate Parts

The following parts were outsourced:
1. Dropouts
2. Bottom bracket shell
3. Head tube
4. Fork

Figure 1: Bottom Bracket.

Figure 2: Dropout Showing Jig Design.

Step 2: Heat treating the Bamboo

This is one of the vital parts in the construction of bamboo bicycle. The bamboo was heated evenly and slowly using a blow lamp. The first step was to turn the green sections to a light brown and the second step was to turn the light brown sections to a dark brown. The heat treated bamboo was thereafter cut to the required sizes.

Figure3: The Green Bamboo Turning Into Light Brown.

Figure 4: The Dark Brown Bamboo Ready for Use.

Step 3: The JIG Design and Assembly

A key piece for assembling the frame together was first built. The jig keeps the tubes together in a specific geometry while being wrapped with carbon tape and epoxy before curing as shown in Figure 4.

- The first step was to cut the tubes to a ballpark length to fit the jig
- The tubes were then mitered with a large end mill, roughly the size of the head tube and bottom bracket shell to which they mate
- A Dremel was then used to miter the small diameter chainstays and seatstays as well as perfect the miters of the larger tubes.
- Epoxy was used to "glue" it together. To connect the tubes together, we used unidirectional carbon fiber tape. The tape was dipped in an epoxy and wrapped around each joint. After curing, the joints were extremely sturdy. Special attention was paid to area prone to experience higher stresses, applying extra wrapping.
- The bottom bracket and a head set are assembled to the frame. The cranks and chain, the wheels and bar, and the seat post were also assembled to the frame.

Figure 5: The Jig Design of the Bamboo Bicycle.

Figure 6: The Main Frame of the Developed Bicycle.

RESULTS AND DISCUSSIONS

Simulation and Analysis of the Bicycle was done with modern Simulation and Finite Element Analysis software (PRO/E, Comsol Multiphysics and Abaqus). The results are shown below:

Stress and Displacement Analysis

From the analysis performed and shown in figure 7, the most fragile area was identified as being the tubes near the bottom bracket, this prompted additional extra carbon fiber wrapping during assembly.

Due to the nature of Nigeria's (developing country) road, we simulated a pothole situation shown in Figure 9. This was done by assigning a horizontal force of 1000N to the front tire of the bicycle.

The analysis showed that the highest stress would occur nearest to the point of impact with the pothole. This led to a decision to wrap the carbon fiber farther down on these tubes for additional reinforcement.

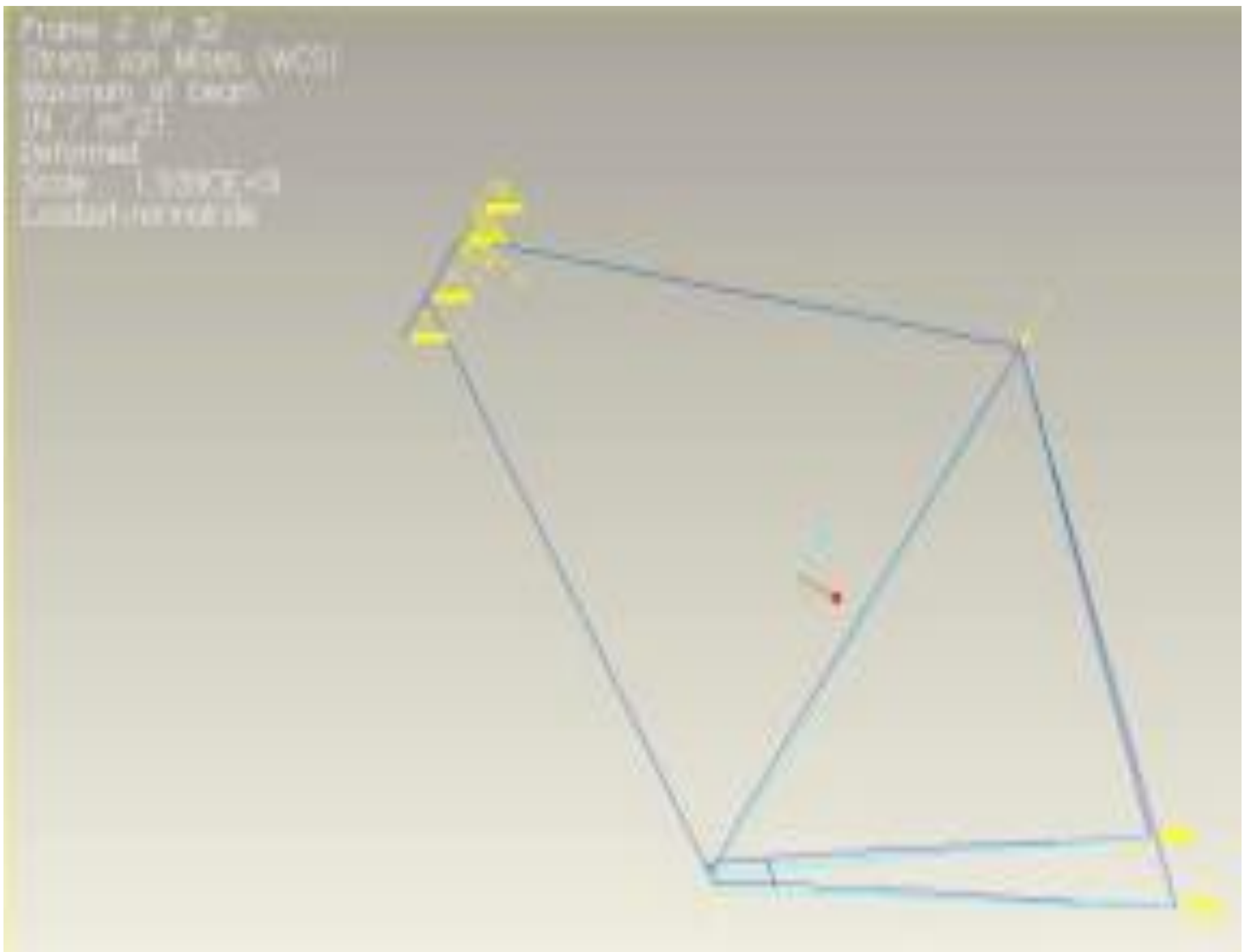

Figure7: Stress and Displacement Analysis.

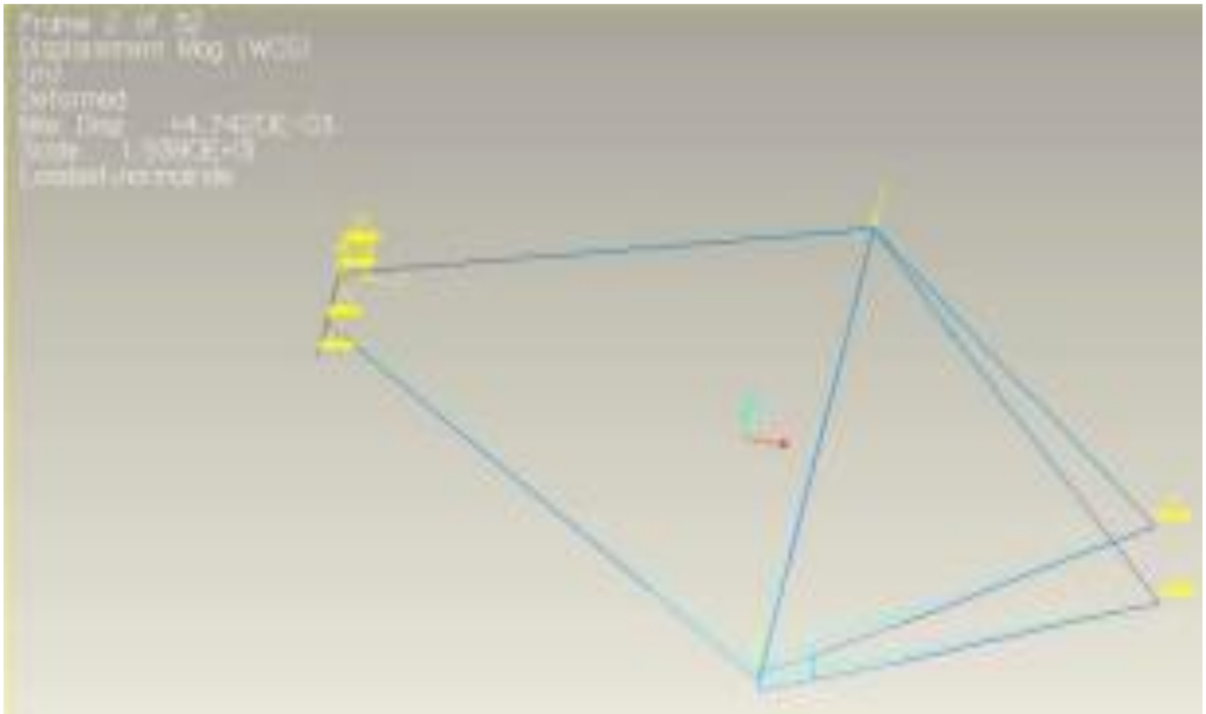

Figure 8: Displacement Analysis.

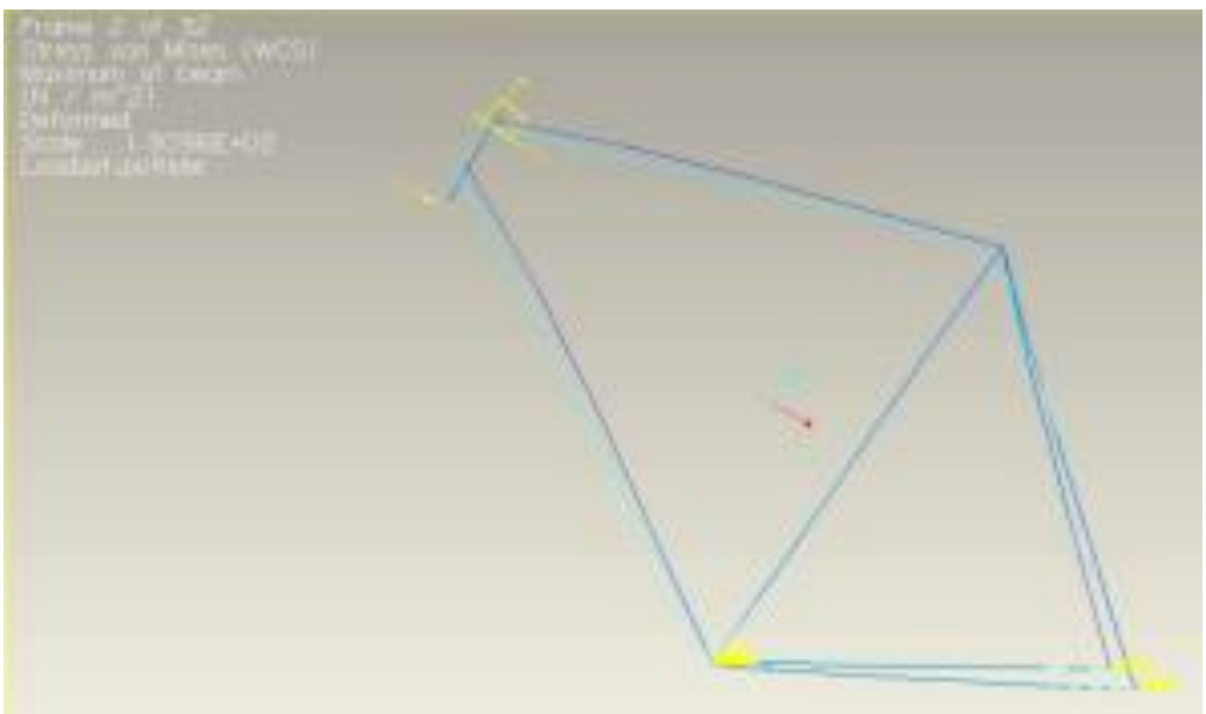

Figure 9: Pothole Stress Analysis of the Frame.

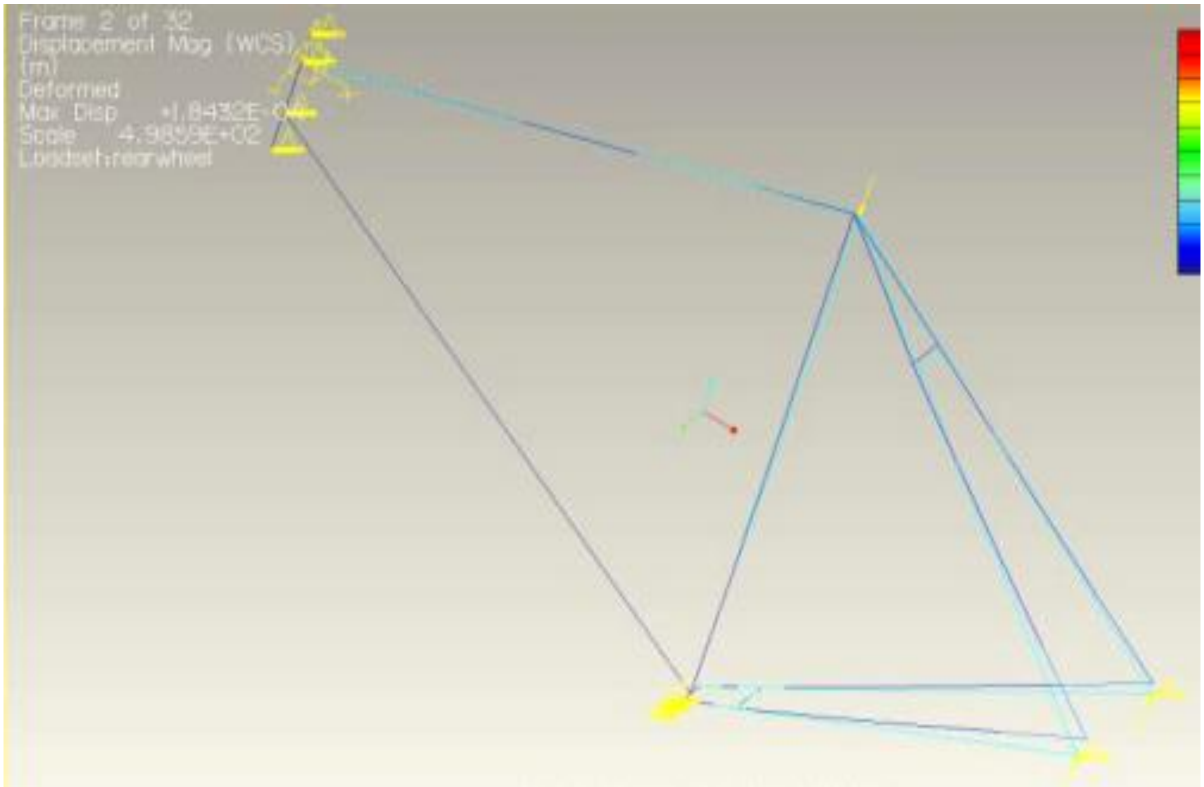

Figure 10: Displacement Simulation of the Rear Wheel Load.

A vertical load on the rear side of the bicycle simulation reveals the above result (shown in the diagram). This can be done by simulating the back wheel hitting down into a hole or landing on this area. The analysis showed a large displacement on the area connected to the dropouts. This is vital in the design of a very strong dropout that would be stable even under large displacements.

CONCLUSION

Before now, the problem of transporting harvest produce, moving commodities to market by rural dwellers, and establishing ease of commuting by low income earners in the urban areas, used to be of great concern because of the cost in transportation. But from the results of this work, it is not only possible to develop an inexpensive locally sourced material bicycle, but also a bicycle that is ergonomically suited for Africa's infrastructure environment. This method can therefore be extended to other means of transportation.

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