TENSILE TESTS OF ABACA FIBER AS ONE OF ALTERNATIVE MATERIALS FOR RETROFITTING OF UNREINFORCED MASONRY (URM) HOUSES

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Abstracts

The vulnerability of Unreinforced Masonry (URM) structures have been proved by many big earthquakes in the past, due to their low seismic capacity. Most URM buildings are built with little or no consideration of seismic loading, and these are not capable of resisting the expected seismic ground motion, which caused damage and collapse of the buildings and have been the major cause of human and economic losses during the past earthquakes.There are many kinds of retrofitting materials and methods have been developed and used to strengthen the URM houses, such as Fiber Reinforced Polymers (FRP), steel mesh cage, surface treatment using Shotcrete, post-tensioning using rubber tires, etc. However, they are relatively expensive and not available in many parts of the world, which is of prime importance in the third world countries. Therefore, we propose to use a natural fiber called Abaca fiber, which is a locally available and inexpensive material with high tensile strength. In this paper, tensile test of Abaca fiber has been investigated. Based on the results obtained from the tests, it can be concluded that Abaca fibers have high potential for retrofitting material of URM houses in developing countries.

INTRODUCTION

Natural fiber reinforced cement composites have been getting attractive during last years, especially for low cost building construction in developing countries [1-2]. It has been reported that natural fibers, such as Sisal, Roselle, Coconut, Sugar cane bagasse, Hemp, and Jute, etc. improve the compressive and tensile strength of the cement based composites [3-8].

Abaca fiber is known as one of the strongest natural fibers, native to the Philippines and widely distributed in the humid tropics countries including Indonesia. In the last years, natural fibers reinforced composites have received high attention due to their low density, excellent thermal properties, low cost, biodegradability, availability, non-toxicity and absorbing CO2 during their growth [9-12]. It has been reported that Abaca fiber is resistant to rotting and has a high tensile strength, and a specific flexural strength comparable to that of glass fiber [13]. Only a few research has been done using Abaca fiber as a retrofitting material of unreinforced masonry (URM) houses. This paper is an attempt to contribute to the development of a new retrofitting material for URM houses strengthened with FRM and ARM subjected to diagonal compression test, considering both mechanical aspects (high strength, large deformation and energy dissipation capacities), and social aspects (local availability, easy applicability, and affordability).

LITERATURE REVIEW

Abaca, common name for *Musa textilis*, is a species of banana native to the Philippines, grown widely as well in Borneo and Sumatra [14]. Abaca fiber, unlike most other leaf fibers is obtained from the plant leaf stalks (petioles). Although sometimes called Manila hemp, Cebu hemp, or Davao hemp, it is not related to true hemp. Abaca fiber, known worldwide as Manila hemp, is obtained from the leafsheath of the Abaca plant. Abaca is indigenous to the Philippines and is similar to banana in appearance except that the leaves are upright, pointed, narrower and more tapering than the leaves of the banana. Abaca fiber is considered as the strongest among natural fibers. The length of the fiber varies from three to nine feet or more, depending on the height of the plant and the age of the leafsheath. The color of the fiber ranges from ivory white to light and dark brown. Abaca fiber, valued for its strength, flexibility, buoyancy, and resistance to damage in saltwater, is chiefly employed for ships' hawsers and cables, fishing lines, hoisting and power-transmission ropes, well-drilling cables, and fishing nets. Some Abaca is used in carpets, tables, fabrics, mainly used locally for garments, hats, and shoes.

Abaca is a species of the Musaceae family (banana plants) with little non-edible fruits full of seeds. Its pseudostem can grow up to 6.5 m and is build of 10 – 25 sheaths that grow from a central core, so that the oldest sheaths are located at the stalk periphery [15]. Abaca has been a source for natural fibre bundle extraction for decades and has been reported as a widely used fibre in the beginning of the 20th century. It was used to fabricate cordage, ropes, and cables, but also woven textiles, coiled baskets, bags, laces, hats, and furniture were manufactured from Abaca [16-17]. Today the major product from Abacá is pulp for the paper production. However, there is much ongoing research activity investigating Abacá reinforced natural fibre composites.

Figure 1 Abaca Plant and Abaca Fiber [14]

The major advantage of fiber reinforcement is to impart additional energy absorbing capability and to transform a brittle material into a pseudo ductile material. Fibers in cement or in concrete serve as crack arrestor which can create a stage of slow crack propagation and gradual failure. Application of natural fibers to replace asbestos because of their availability in the tropical and subtropical parts of the world has been explored. The study found that vegetable fibers are acceptable as substitutes for asbestos as reinforcements in cement-based sheets. Replacement of asbestos fibers is seen as an area of priority research, particularly in developing countries, where apart from health problems low cost materials are urgently needed. Natural cellulose fibers have been produced either as a full or partial substitute for asbestos because they have similar characteristics such as high aspect ratio, high tensile strength, toughness, flexibility and above all, the buoyancy of the fiber in the cement.Mechanical and chemical properties of Abaca fiber are presented in Table 1 and Table 2.

Table 1 Mechanical properties of Abaca fiber

Density (g/cm^3)	Tensile strength (MPa)	Tensile modulus (GPa)	Specific modulus (approx) (GPa)	Elongation (%)
1.5	400-980	6.2-20	9	1.0-10

Table 2 Chemical properties of Abaca fiber

Cellulose (wt.%)	Hemi-cellulose (wt.%)	Lignin (wt.%)	Pectin (wt.%)	Waxes (wt.%)	Moisture content (wt.%)
56-63	20-25	7-13	1	3	5-10

TENSILE TEST OF ABACA FIBER AND ABACA ROPE SPECIMEN CHARACTERISTIC AND CONSTRUCTION PROCES

The axial tensile tests of Abaca fiber were conducted by using the Universal Testing Machine (UTM) Shimadzu EZ-L 200 N with constant loading rate (10 mm/min). Seven specimens with 40 mm length single fiber pasted by glue to the paper were prepared. Diameter of Abaca fiber varies from 0.13 mm to 0.2 mm. The axial tensile tests of Abaca fiber were performed and the results shown in Figure. 5 were obtained. Most of samples showed brittle failure, while some samples still have some deformation capacities. The average tensile strength and strain were 957 MPa and 4.3 %, respectively. The preparation of the specimens was performed according to ASTM C1557 [10]

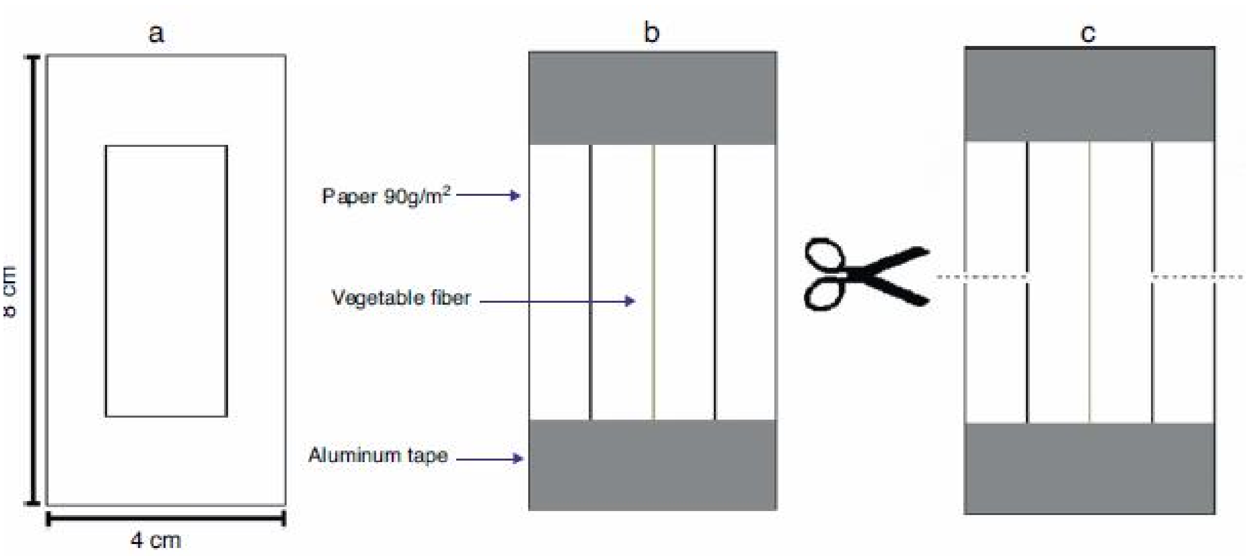

Figure 2 Preparation of specimen for the tensile test: (a) paper for fixing the fibers, (b) fibers fixed in the paper and (c) detail of the cutting of the paper before the test.

TEST SETUP

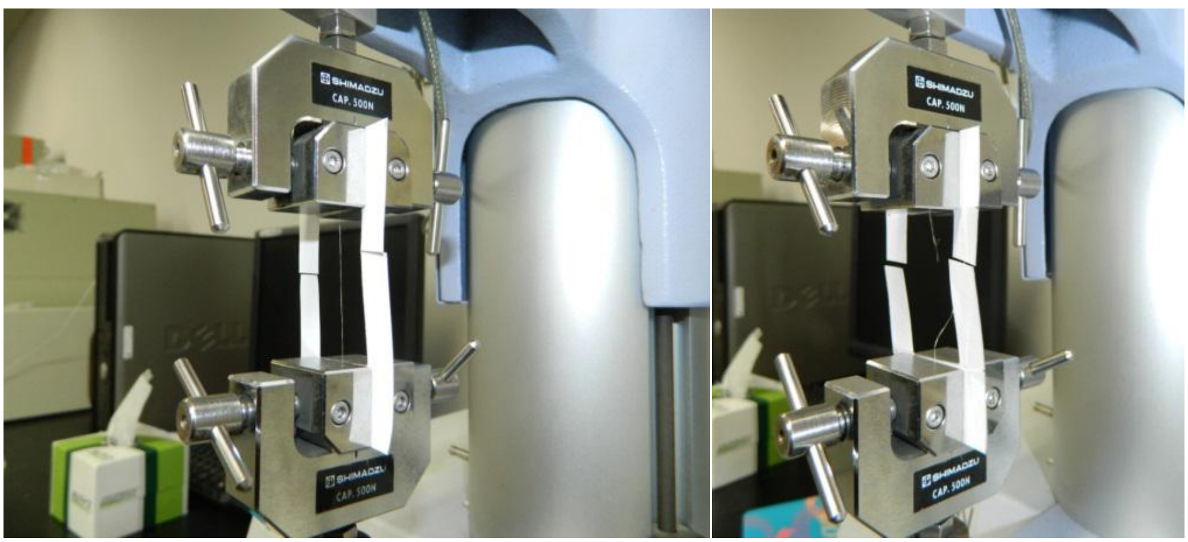

Figure 3. Tensile test of Abaca fiber before test (left) and after test (right)

TESTING PROGRAM

TEST RESULTS

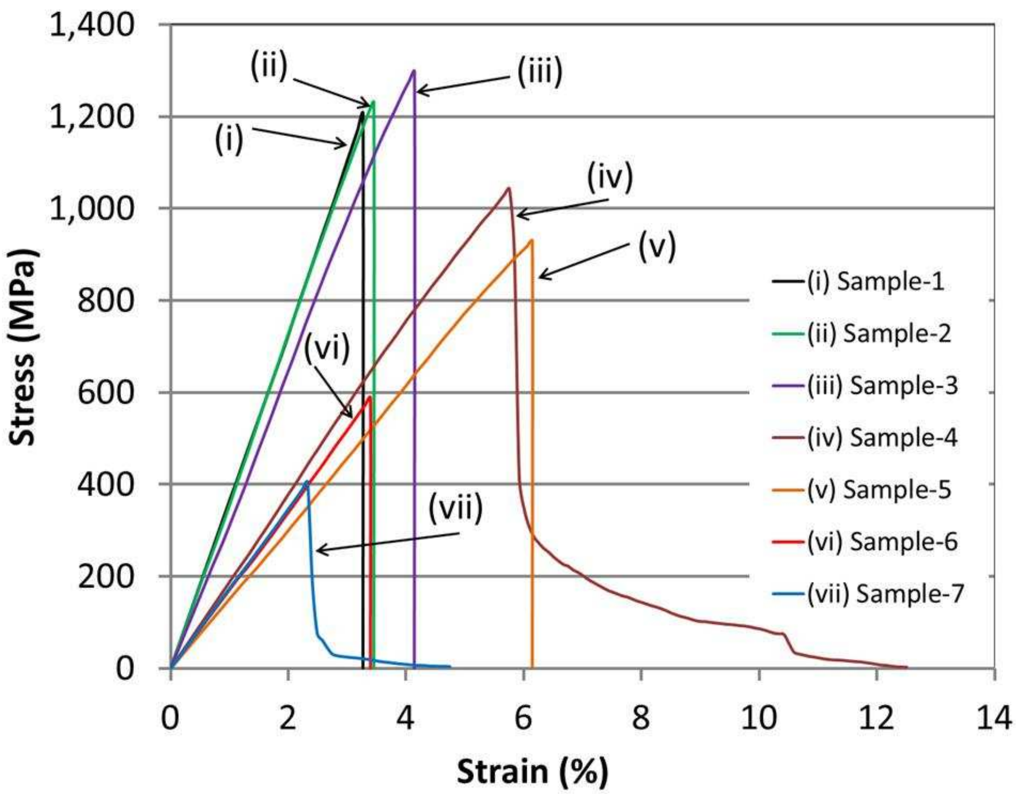

Figure 5. Results of Tensile test of Abaca fiber

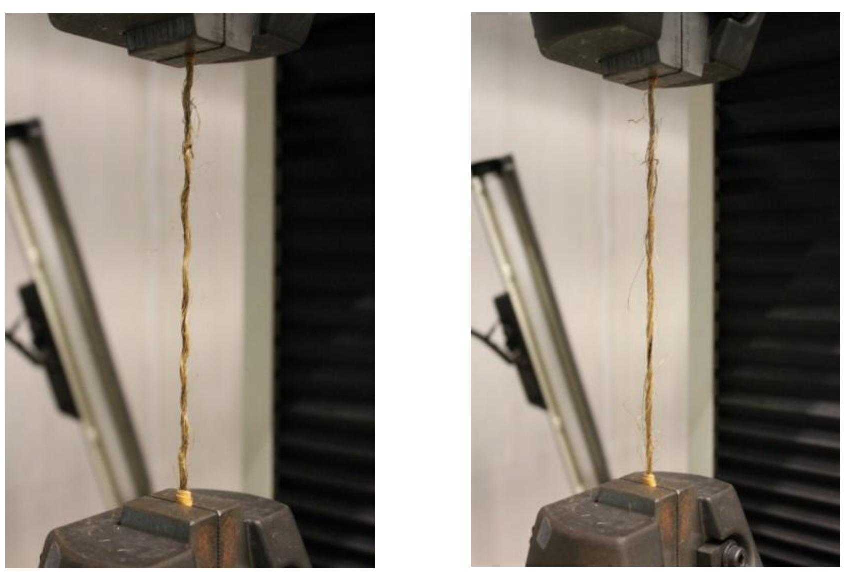

Figure 6Loading rate 2 mm/min (Abaca rope)

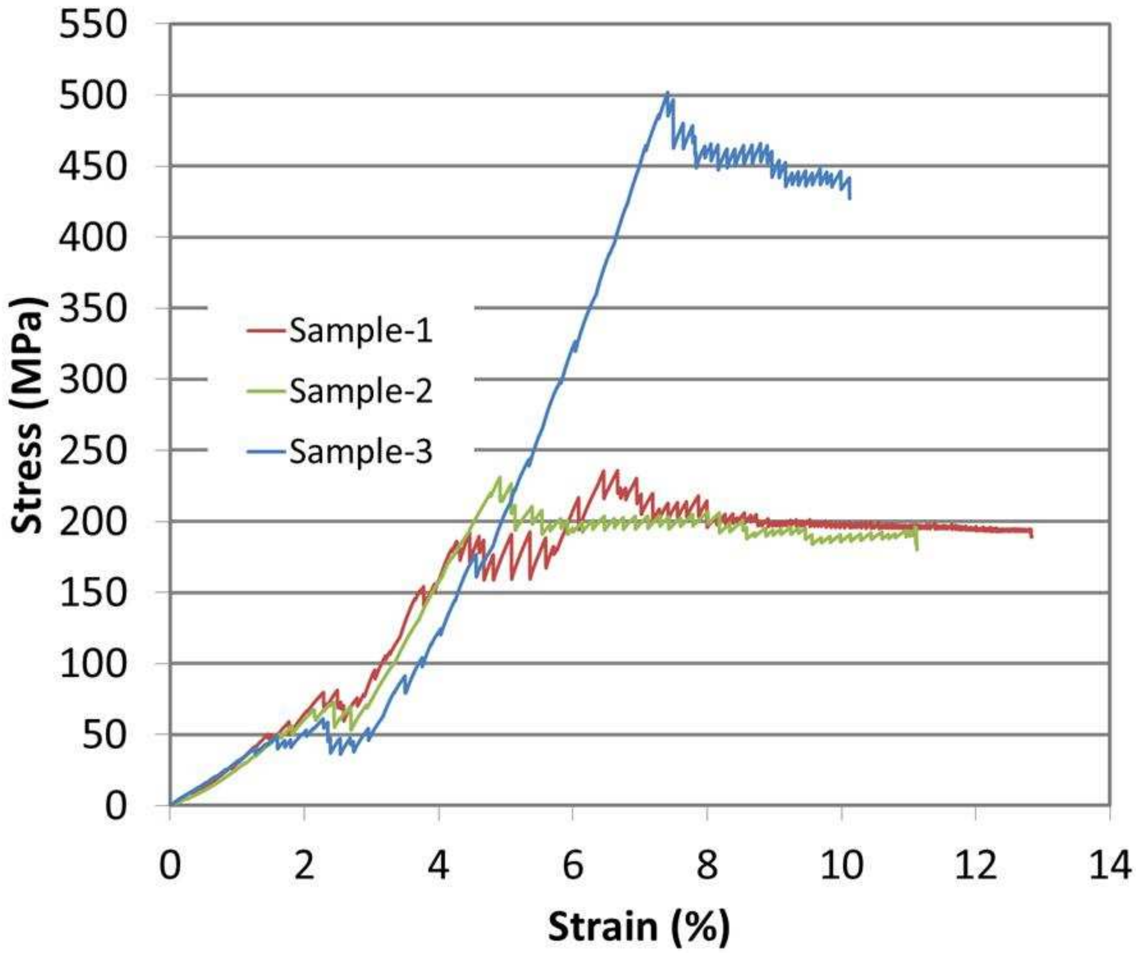

Figure 7. Results of Tensile test of Abaca rope

Fig. 7 exhibited the axial test of Abaca rope using Autograph Shimadzu 50 kN. Three samples of Abaca rope were tested under displacement control systems as shown in Fig. 6 and the results are shown in in Fig. 7. The diameter of Abaca rope varies between 2 mm up to 3 mm and 150 mm in gauge length. Based on the test results, the average strength and strain of Abaca rope are 320 MPa and 11.3 %, respectively. Even showed a less stiffness than Abaca fiber, but Abaca rope still has high tensile strength and bigger deformation capacity than that of Abaca fiber.

CONCLUSIONS

Based upon the experimental results, it can be concluded that Abaca fiber have high potential for retrofitting of URM houses in developing countries.The average tensile strength and strain of Abaca fibers were 957 MPa and 4.3 %, while the average strength and strain of Abaca rope are 320 MPa and 11.3 %, respectively.From the tests, it can be seen that Abaca fiber showed high tensile strength and deformation capacity.Following researches regarding in plane test, out-of-plane test, shaking table tests, and durability of this composites will be reported in other papers by the authors.

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