



Kenaf Building Blocks

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Abstract. Kenaf fibers are emerging as promising alternative building materials that will provide a much needed boost to the construction industry. The objective of this investigation is to use Kenaf, a fast growing sustainable agricultural fiber to produce wall building blocks as an alternative to using wood products for wall construction in buildings. The aim is to produce a low-cost wall building material that will provide affordable housing to meet global housing need. The method employed is to use a low-energy and cost effective process to make kenaf blocks by mixing kenaf, an agricultural fiber, with Magnesium Oxychloride cement, an organic binder and water to produce a matrix that can be placed in molds to produce the blocks. The blocks made are light weight with an average weight of 10.365 pounds, an average unit weight of 78.79 pounds per cubic foot and have an average compressive strength of 2768.68 psi with a maximum strength of 3515 psi, which is sufficient for walls in one story construction. Undergraduate Research Assistants were involved in the execution of the project and learned principles of basic research and engineering characteristics of kenaf building blocks. The blocks gained compressive strength steadily attaining about 50% of the target strength in 15 days. The blocks made are light weight and strong and may be very cost effective when used in one story buildings.

Keywords: Sustainable Agricultural-based Fibers, Kenaf blocks, Magnesium Oxychloride cement, wood-based fiber products, maximum average compressive strength.

Introduction

Kenaf is an old crop with roots in Africa. A member of the hibiscus family (*Hibiscus cannabinus* L), it is related to cotton and okra, and grows well in many parts of the world. Kenaf grows quickly, rising to heights of 16-20 feet in as little as 4 to 5 months. U.S. Department of Agriculture studies show that yields of 6 to 10 tons of dry fiber per acre per year are generally 3 to 5 times greater than the yield for Southern pine trees, which can take from 7 to 40 years to reach harvestable size [1].

Kenaf has two fibers: the outer fiber called "bast" and comprises roughly 40% of the stalk's dry weight and the whiter, inner fiber called "core". Upon harvest, the whole kenaf plant is processed in a mechanical fiber separator, similar to a cotton gin. The separation of the two fibers allows for independent processing and provides raw materials for a growing number of products including paper, particle board, animal bedding and bioremediation aids [2]. The stem, leaves and flowers of the plant are shown in Figure 1.

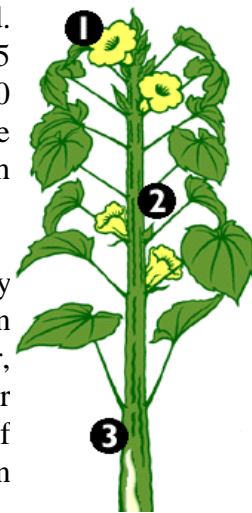


Figure 1 Kenaf Plant

LEGEND: 1. Flower, 2. Stalk-Outer Fiber = Bast (40%), 3. Stalk-Inner Fiber = Core (60%)

Increasing needs for environmental protection has attracted the international community to the development of raw materials based on kenaf fibers that can replace wood and fiberglass with less adverse impact on the environment. The kenaf plant's short term growth cycle allows it to absorb and decompose carbon dioxide in the atmosphere very rapidly to fix carbon as an integral component of fibers that comprise the plant. Due to its intrinsic process of rapid absorption and decomposition of carbon dioxide in the air and carbon fix remains for a long time, growing of kenaf also helps reduce ever-increasing carbon dioxide in the atmosphere. Among other things, kenaf offers many advantages such as higher yields per planted acreage and fewer years in comparison with other well-known fast growing trees such as poplars and eucalyptus. Its fast growth and easy process ability makes kenaf products ecologically friendly [6,7].

This paper presents the results of an investigation using kenaf fibers and Magnesium Oxychloride cement mix in making building blocks. This project can be readily be used as an Independent Study/Research for students in construction related projects.

Materials

The kenaf fibers used in this project are shown in Figure 2. They were obtained from a kenaf processing plant in Texas, USA. The plant manufactures kenaf products including Kenaf decks.



Figure 2 Kenaf Fibers

Magnesium Oxychloride Cement Mix Design

The Magnesium Oxychloride Cement is the bonding agent in this work [3,4,5]. With the right mix proportions, the Magnesium Oxychloride cement binds the fibers into a lightweight solid mass with high compressive strength. The Magnesium Oxychloride Cement mix design to obtain the high strength posed the greatest challenge in this work. Several mixes yielding increasing strengths were designed until the optimum mix design for making the kenaf blocks was obtained. A typical

trial mix proportion used in the project was: bast fiber (250 gm), core fiber (250 gm), Oxychloride cement mix (3562 gm)



Figure 3 Grinding the Fibers

Kenaf Block Making Process

The procedure for making the blocks was as follows:

- The kenaf fibers were first ground and reduced to fine sizes. Figure 3 shows the grinding process. The grinding, mixing and testing of the blocks were carried out by undergraduate student Research Assistants.
- The Magnesium Oxychloride cement was then designed.
- The blocks were made by mixing the fibers, water and Magnesium Oxychloride cement in different proportions.
- The mixture was then poured into 6 inches x 6 inches x 6 inches steel molds. After adequate compaction and vibration, they were left for 24 hours before the blocks were removed from the molds. See Figure 4.
- The blocks were left at room temperature to cure (gain strength) and tested for compressive strength at several different days after casting
- The blocks were tested for compressive strength using a a Tinius Olson universal testing machine. See Figure 5.



Figure 4 Kenaf Fiber Processing and Block Making

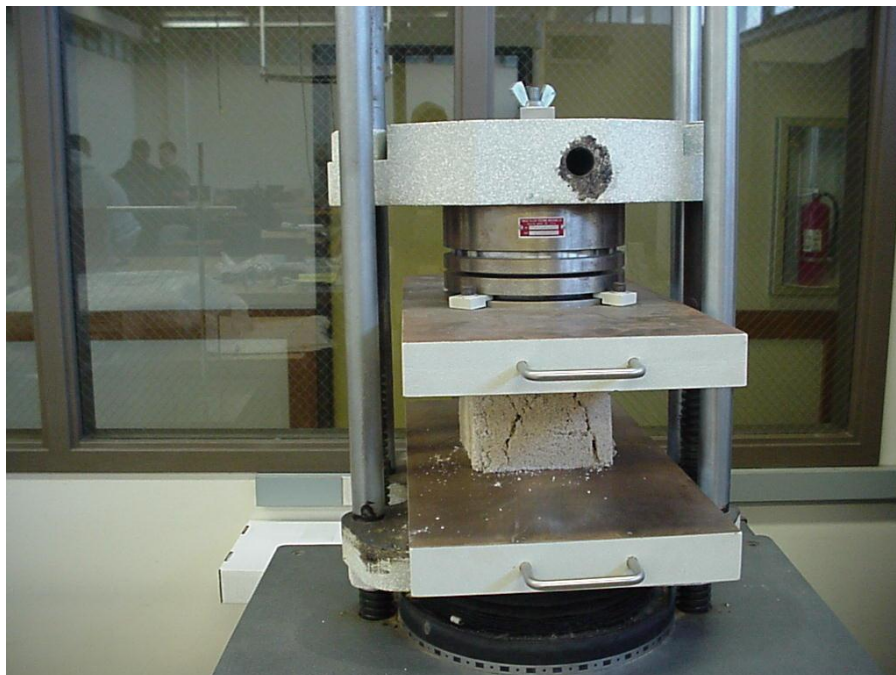


Figure 5 Compression Test on a Kenaf Block with the Universal Testing Machine

Data Collection

The following information were noted for each block made: date of manufacture, volume, weight, Oxychloide mix proportions, proportions of kenaf fibers used, compression strength and date of compression test. From this information, the densities or the unit weights of the blocks were computed.

Results and Analysis of Data

The results of the compression tests are shown in Table 1. The data collected were analyzed to identify specific characteristics and trends of the kenaf blocks such as:

- The largest unit weight = 87.97 pcf with a compressive strength of 3247.29 psi
- The average compressive strength = 2786.68 psi.
- The design mix of kenaf fibers and Magnesium Oxychloride cement to produce the largest compressive strength was noted.

Undergraduate Student Engagement

Construction education programs incorporate courses in construction materials including concrete, masonry, timber and steel in their curricula. In addition to these proven construction materials, evolving alternative materials such as kenaf blocks may also be covered in the courses. In addition, undergraduate research has become a common method of engaging students early to the possibility of being scientists and future researchers. Descriptive studies suggest intellectual gain is associated with undergraduate research [8]. A few very well-designed assessment studies have demonstrated that students involved in research perceive an intellectual gain from such experiences. This type of project is quite suitable for Independent Study/Research by a student or a group of students. For this type of study, the Faculty prepares a contract for the student(s) that details the scope of work to be accomplished and the deliverables including a final report detailing the procedures and results obtained. It is known that research invariably leads to a better understanding of and a deeper appreciation for the material under investigation.

Several undergraduate Construction Management Technology students were involved in this project as Research Assistants. They were involved in all aspects of the project including material procurement, mix design, production and testing of the kenaf blocks. The project had an impact not only on the students who participated in it, but also on all students in the Construction Management Technology program as it deals with issues that will eventually affect the construction Industry as a whole, a field which most of the students in the program are destined to eventually get into. The project can be used in courses like Construction Materials and Construction Methods that deal with materials, sustainability and techniques in construction. It can also be used as an Independent Study/Research for a student or a group of students. Overall, on educational goals, the students thought the project gave them an in-depth look into the basic processes for finding the right and highly dependable alternative sustainable construction materials that can be used for building houses.

Table 1 Kenaf Blocks Compression Test Results

DATE OF COMPRESSION TEST: JUNE 8, 2011

Date of Manuf.	Specimen Number	Length (IN) (L)	Width (IN) (W)	Height (IN) (H)	Area (LxW) (A)	Volume (AxH) (V)	Weight (LB)	Unit Wt LB/FT³ (W/V)	Compressive Load (LB)	Compressive Strength (PSI)	Strength/ Weight Ratio
6/2/2009	1	6.189	6.006	6.057	37.17113	225.1456	10.182	78.1472	96,000	2582.649	253.6485
5/8/2009	2	6.034	6.075	6.056	36.65655	221.9921	9.8416	76.60762	95,000	2591.624	263.3336
5/8/2009	3	6.04	6.1	6.138	36.844	226.1485	9.704	74.14824	91,000	2469.873	254.5211
5/8/2009	4	6.124	6.135	6.139	37.57074	230.6468	9.02	67.57762	88,500	2355.556	261.1482
5/8/2009	6	6.02	6.049	6.048	36.41498	220.2378	9.728	76.32652	128,000	3515.037	361.3319
5/13/2009	8	6.054	6.035	6.023	36.53589	220.0557	8.034	63.08746	63,000	1724.332	214.6293
6/2/2009	11	6.25	6.031	6.04	37.69375	227.6703	11.272	85.55363	110,000	2918.256	258.8942
6/2/2009	12	6.153	6.043	6.07	37.18258	225.6983	11.27	86.28582	120,000	3227.318	286.3636
6/2/2009	13	6.038	6.185	6.186	37.34503	231.0164	11.07	82.80349	111,000	2972.283	268.4989
6/2/2009	14	6.16	6.049	6.042	37.26184	225.136	11.462	87.97497	121,000	3247.29	283.3092
6/3/2009	15	6.149	6.113	6.139	37.58884	230.7579	11.252	84.25912	112,500	2992.91	265.9891
6/3/2009	16	6.276	6.165	6.23	38.69154	241.0483	11.542	82.741	110,000	2842.999	246.3177
AVERAGE							10.365	78.7927		2786.68	268.165

Kenaf Block Strength Growth Rate

The blocks increased in strength continuously after they were made. The Test Results show that in about 15 days, over 52.46% of the long term strength had been achieved as shown in Table 2.

Table 2 Compressive Strength Growth Rate

S/N	Time (Months)	Compressive Strength (psi)	Percentage of 30 Months Strength
1	≈ ½	1462	52.46
2	2	1825.97	65.52
3	8	2033.33	72.96
4	30	2786.68	100

Table 3 Water Absorption of Kenaf Blocks

Block #	Weight Before Soaking (LBS)	Weight After Soaking (LBS)	Percentage Weight Change
6	9.728	10.25	5.57
12	11.27	11.5	2.04
14	11.462	11.75	2.51

Compression Test Failure and Water Permeability of the Kenaf Blocks

The Kenaf blocks made with the optimum design mix when tested after proper curing produced “ductile” type failures with failure line seen on the block surfaces, Figure 6. These blocks were soaked in water for four days after the compressive test was performed. The result showed that the weight change after soaking was small. See Table 3.



Figure 6 Kenaf Blocks Failure Patterns

Challenges

The problems encountered involved the processing of the kenaf fibers and designing the optimum Oxychloride design mix.

Cost of Kenaf Block Wall Construction

To evaluate the viability of the kenaf block wall construction, preliminary cost estimates were made on an 8 feet by 8 feet wall. The cost estimate for the kenaf blocks was comparable to cost of the installed price of an average Concrete Masonry Unit (CMU) wall construction which is \$10.65 per square foot according to the Masonry Advisory Council.

Conclusion

Building blocks were made from kenaf fibers and Magnesium Oxychloride cement. Students were involved in the preparation and testing of the blocks. This type of project is quite suitable for Independent Study/Research by a student or a group of students. The blocks were light weight and the maximum average compressive strength obtained was 3515 psi and the lightest unit of the blocks was 63 pounds per cubic foot. The blocks gained compressive strength steadily, attaining about 50% of the target strength in 15 days. This research produced a low-weight and high-compressive strength block from sustainable kenaf fibers that can be used in building wall construction. Preliminary cost estimates show that the cost of production of the kenaf blocks may be comparable to that of concrete masonry units. The implication of the study is that wall building blocks can be made with a low-tech and a low-energy consuming method using a rapidly growing alternative fiber to wood products that is grown in many parts of the world. This will be a great boost to the production of housing to meet global needs.

Recommended Future Work

As a follow-up to this work, the following needs investigating:

1. Moving the work from laboratory level to full-scale production with emphases on kenaf fiber preparation and Oxychloride mix design. A production manual needs to be prepared.
2. Preparing a comprehensive comparative wall construction cost analyses for the kenaf blocks, concrete masonry units and light wood frame construction.

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