COMPRESSED AND STABILIZED EARTH BLOCKS REINFORCED WITH SUGARCANE BAGASSE FIBER

LSU College of Engineering
Department of Civil & Environmental Engineering

Nitin Kumar (Dr. M. Barbato)

7th Annual Graduate Student Research Conference

Abstract: This study investigates the effect of sugarcane bagasse fiber (SBF) (which is an agricultural by-product that is abundant in Louisiana) on the strength and durability properties of CSEBs. CSEBs were fabricated using native soil and SBF from Baton Rouge with a manually-operated compression machine. Different amounts of SBF (0%, 0.5%, and 1.0% in weight) and Type-II Portland cement (0%, 6%, and 12%) were considered. The flexural and compressive strength of the CSEBs were tested experimentally. The CSEB durability was examined by measuring their mass loss, dry density, water absorption, and wet compressive strength after 12 wetting/drying cycles. Student's t-test was used to investigate the statistical significance of the obtained experimental results. The research results indicate that a 0.5% amount of SBF can significantly improve the mechanical properties of CSEBs. This study also showed that, although the CSEBs with SBF had lower density, higher water absorption, and higher mass loss during the wetting/drying cycles, they also achieved a higher final wet compressive strength.

Introduction

- Earthen construction using compressed and stabilized earth blocks (CSEBs) can be used for low-cost eco-friendly housing in hurricane prone regions [1].
- CSEBs are made from mechanically compressed soil of appropriate composition, stabilized with a chemical binder such as Portland cement.

Motivation:

- CSEBs are generally brittle in tension.
- Natural fiber can be used to improve the brittle behavior in tension.
- Sugarcane bagasse fiber is abundant in Louisiana, with about 12.41M ton of sugarcane and 3.87M ton of bagasse fiber in 2016 [2].

Significance:

- Solve the disposal problem of sugarcane bagasse fiber (SBF).
- Provide affordable housing for low-income households in Louisiana, where more than 386,000 households cannot afford a house [3].

Objective:

- To investigate mechanical and durability properties of SBF reinforced CSEBs.

Materials and Methods

Soil

- Obtained from W.A. Callegari Environmental Center, LSU.

Physical properties of soil	Values
Particle size distribution	
Gravel (>2 mm) (%)	<1
Sand (2–0.063 mm) (%)	10
Silt (0.063–0.002 mm) (%)	58
Clay (<0.002 mm) (%)	31
Atterberg limits	
Liquid limit LL (%)	35.47
Plastic limit PL (%)	22.94
Plasticity index PI (%)	12.53
Proctor tests	
Optimum moisture content (%)	23.42
Maximum dry density (ton/m^3)	1.57
Specific gravity of soil	2.59

Sugarcane bagasse fiber (SBF)

- Obtained from Alma Plantation sugarmill in Lakeland, LA.
- Average length and thickness of the SBF was 55 mm and 0.2 mm.

Cement

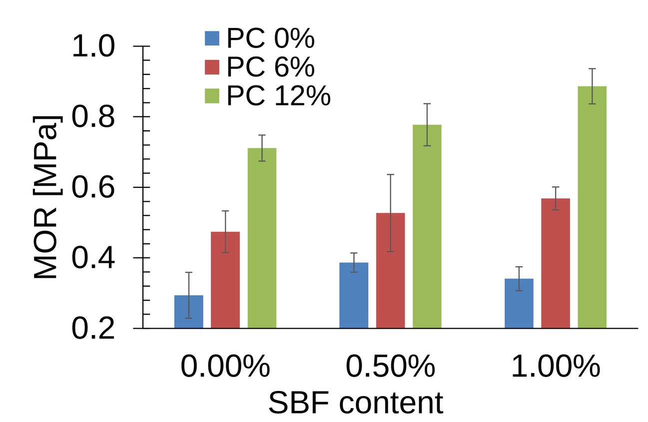
- Type II Portland Cement (PC).

Test Matrix

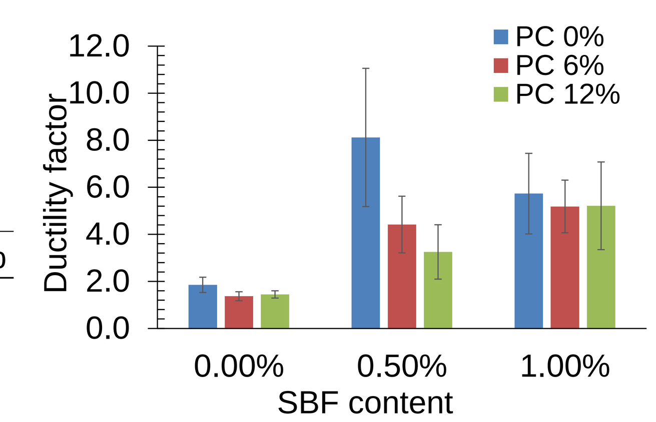
- CSEBs of dimension 290x150x75 mm^3 were made by varying percentages in weight (wt%) of SBF (0 wt%, 0.5 wt%, and 1.0 wt%) and PC (0 wt%, 6 wt%, and 12 wt%).
- 8 blocks were made for each of nine different soil mixes (72 blocks total).

Flexure test

- 5 specimens for each soil-mix were tested for three point bending test.
- The average MOR and ductility factor of CSEBs increased with SBF content for 6% and 12% cement content.
- The t-test for population means confirmed the trend of increase in average MOR and ductility factor.



Modules of rupture (MOR)



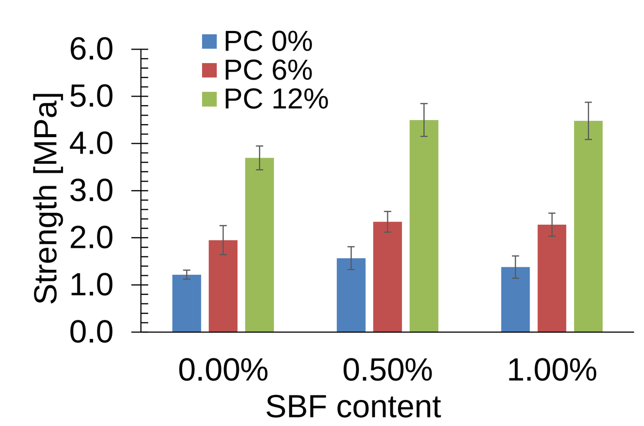
Flexure displacement ductility factor

Flexure test: t-Test's p-value for means of different content of SBF

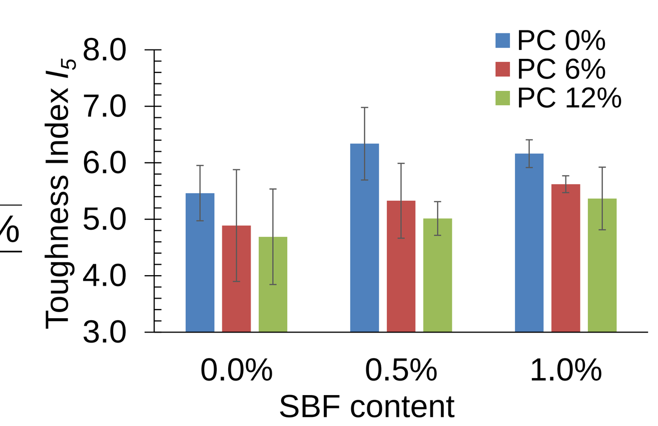
	PC\SBF	0%-0.5%	0%-1.0%	0.5%-1.0%
MOR	0%	0.01	0.11	0.02
	6%	0.27	0.00	0.34
	12%	0.03	0.00	0.00
Ductility factor	0%	0.00	0.00	0.53
	6%	0.00	0.00	0.02
	12%	0.00	0.00	0.02

Compression Test

- 5 specimens of 100x100x75 mm^3 for each soil-mix were tested for dry compression strength.
- CSEBs with 0.5% SBF content had highest average dry compressive strength for all cement amounts.
- Compressive toughness index I_5 of CSEBs increased with SBF content for 6% and 12% cement content.



Dry compressive strength



Compressive toughness index I_5

Dry compression test: t-test's p-value for equal means

	PC\SBF	0%-0.5%	0%-1.0%	0.5%-1.0%
Strength	0%	0.01	0.12	0.16
	6%	0.02	0.04	0.63
	12%	0.00	0.00	0.93
Toughness Index I_5	0%	0.02	0.01	0.50
	6%	0.34	0.08	0.27
	12%	0.34	0.10	0.16

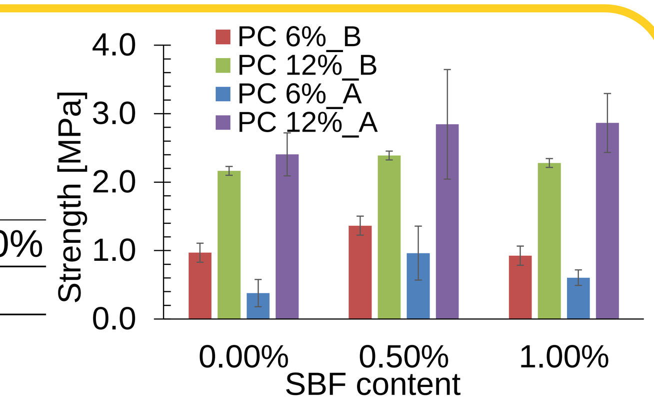
Durability test

Percentage change in mass, dry density, and water absorption

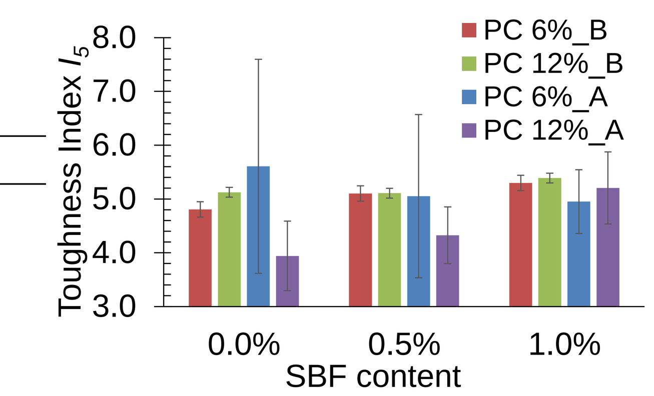
PC [%]	SBF [%]	Loss in mass Avg. [%]	Loss in mass COV [%]	Dry density Avg. [%]	Dry density COV [%]	24 h water absorption Avg. [%]	24 h water absorption COV [%]
6	0.0	13.07	33.33	-2.04	52.71	-2.09	57.97
	0.5	15.13	25.45	-4.76	28.32	3.76	59.99
	1.0	19.63	24.57	-3.81	52.83	2.43	28.08
12	0.0	1.40	53.29	-1.43	92.52	1.60	51.47
	0.5	2.34	25.92	-3.70	70.28	1.29	36.10
	1.0	5.29	30.35	-4.35	38.66	3.84	35.49

Wet compression test: t-test's p-value for means

	PC\SBF	0%-0.5%	0%-1.0%	0.5%-1.0%
CSEBs properties before durability test				
Strength	0%	0.00	0.00	0.00
	6%	0.00	0.47	0.00
	12%	0.04	0.26	0.37
Toughness Index I_5	0%	0.00	0.00	0.00
	6%	0.10	0.04	0.29
	12%	0.96	0.47	0.34
CSEBs properties after durability test				
Strength	0%	0.00	0.00	0.00
	6%	0.00	0.01	0.02
	12%	0.15	0.03	0.95
Toughness Index I_5	0%	0.00	0.00	0.00
	6%	0.51	0.36	0.86
	12%	0.19	0.00	0.01



Wet compressive strength



Compressive toughness index I_5

- 12 cycles of wetting and drying of CSEBs specimens (100x100x75 mm^3) were carried out to investigate durability as per ASTM D559-15 code [4].
- Percentage loss in mass and density increased with increasing SBF content of CSEBs.
- Earth blocks without cement showed zero strength and poor durability.
- CSEBs with 0.5% SBF and 12% cement content provided best strength and durability properties after wetting/drying test.

Conclusions

- CSEBs with 0.5% SBF and 12% cement content can be used for building low-cost eco-friendly dwellings in Louisiana.
- They satisfy minimum strength requirement for compressed earth blocks as per New Mexico Administrative Code.
- They satisfy the requirement of minimum average wet compressive strength of 1.5 MPa [5], even after 12 cycles of wetting and drying.
- They show satisfactory durability after a test comprising 12 wetting and drying cycles.
- They provide best compressive strength and durability properties after the wetting/drying cycles.

Acknowledgements

Partial support for this research by the Louisiana Board of Regents through the Economic Development Assistantship Program, and by the National Science Foundation through award CMMI #1537078 is gratefully acknowledged. All the opinions presented here are those of the writers and do not necessarily represent those of the sponsors. The author would like to thank Ms. Lucy C Farrar, Mr. Alex E Ramirez, Mr. Neal Wright, and Mr. Matthew Gordon for their help during this research.

References

[1] Kumar N, Barbato M, Holton, R. Feasibility Study of Affordable Earth Masonry Housing in the US Gulf Coast. *Journal of Architectural Engineering*, ASCE, forthcoming 2018, accepted and in print.

[2] USDA. 2016 State Agriculture Overview, National Agricultural Statistics Service, USDA, Washington DC, USA, 2017.

[3] LHFA. "Louisiana housing needs assessment 2010 executive summary." GCR & Associates Inc., New Orleans, 2010.

[4] ASTM D559. Standard Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures, ASTM international, West Conshohocken, PA.

[5] Houben H, Guillaud H. Earth construction: a comprehensive guide, Intermediate Technology Publications, 1994.