The Use of Agricultural Fiber in "an Economy that is Restorative and Regenerative by Design"

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This paper presents the findings of an investigation into agricultural "waste" fibers and how they can be used in "an economy that is restorative and regenerative by design", this is the definition the Ellen MacArthur foundation uses to define a Circular Economy.

In 2012, with a desire to investigate if a more interconnected form of production could be fostered in the industrialized agricultural landscape of America's mid-west, research got underway to see if mono-crop cultivation could be replaced with a woody perennial poly culture, interspersed with harvested meadow and grazing crops. Initially the meadow grasses were analyzed for their potential as an annual source of fiber for paper production as opposed to the clear-cut felling of trees for pulp.

In the early years of the project a number of different native and forage grasses were explored to understand their properties and potential for use in paper manufacture. Following a couple of seasons of hands-on experimentation, the research became a more rigorous form of enquiry in which 10 plant types were studied down to the scale of a micron. In the process a number of preliminary findings related to tensile strength and hydrophobicity were discovered.

In 2017 another form of inquiry was initiated to see if various grass fibers could be used in three dimensional constructs. This research focused on three grasses for the following reasons: corn stover, due to its ubiquity across the Midwest, miscanthus because it is a high yielding perennial rhizomic plant, and the

Figure 1. Harvest time: Corn (left) Miscanthus (right). Taylor M.

PROJECT

Corn Coarse

Miscanthus Coarse

Corn Fine

Miscanthus Fine

Fiber-crete mix analysis
% mass fiber mix components sorted by type

	1	2	3	4
Hemp	6.0%	6.5%	30.2%	57.3%
Corn Coarse	10.2%	4.4%	52.7%	32.7%
Corn Fine	16.3%	2.0%	28.3%	53.4%
Miscanthus Coarse	3.9%	54.8%	41.3%	-
Miscanthus Fine	2.8%	45.2%	52.0%	-

Hemp Fine

Fiber-crete mix analysis
% mass fiber mix components sorted by type

	1	2	3	4
Hemp	6.0%	6.5%	30.2%	57.3%
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Miscanthus Fine

Figure 2. Fiber-crete mix analysis. Taylor M, Kovank L.

Figure 3. Grow Your Own Paper. Benson E.

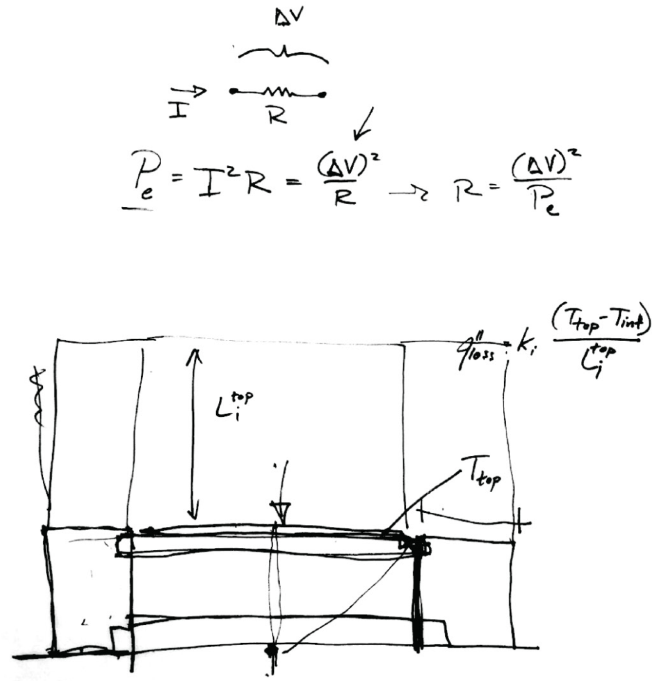

Figure 4. Sketch of test set up and equation. Smith K.

hurd from industrial hemp because it has been used in wall construction since antiquity and provides a good base case for comparative analysis.

Testing the thermal resistant properties of these three different grasses began in April 2018 before a full- scale mock up wall assembly was constructed in the Spring of 2019. In addition to the grass fibers, which are milled to a somewhat uniform dimension, hydrated and hydraulic lime are combined to form a binder that will harden over time and prevent the fiber from being affected by mold or insect attack. Initial results were very similar for the three grasses tested with both miscanthus and corn stover slightly out performing hemp with an average conductivity of 0.1 W/mK or an R value of 1.3 per inch.

In the summer of 2019, having completed the construction of a full-scale mock up wall, the restoration of a shed measuring 20' x 15' began. Once decayed timber has been removed and the building stabilized the building will be retrofitted with different mixes of agricultural fiber and lime binder to see how the different grasses perform over time. Hempcrete has long been recognized for its ability to both handle and resist moisture. As Chris Magwood explains in his book Essential Hempcrete Construction "Like all of the plant-fiber insulation options, hemp hurds are able to store a great deal of moisture because of their porous structure; the moisture is adsorbed onto the large internal surface area of the plant fibers and absorbed into the cellular structure. This storage capacity is very helpful in allowing the material to take on moisture when it exists and to release it when conditions allow." This capacity to take on and release moisture has historically been described as "breathable construction"; vapor permeable would be a better descriptive term, as uncontrolled air flow through a wall assembly is never a good thing when trying to maintain a desirable interior temperature. Having established miscanthus and corn stover have similar thermal resistant properties as hemp hurd this field study will provide information as to whether these three plant fibers can handle moisture equally well or whether their composition affects their performance in a wall assembly.

No specific testing has been carried out on the plant fiber that will be installed in the walls of the shed, however data from peer-reviewed literature points to some general composition traits that consider variation on where the plants were grown, in which soils, and when they were harvested. All three plant types are composed of Cellulose in a range between 39% for Miscanthus, 41% for Corn Stover, and 44% for Hemp Hurds. For Hemicellulose the range is from 19% for Miscanthus, 31% for Corn Stover, and 25 to 33% for Hemp Hurds. The content of woody Lignin in the three samples is probably the most cause

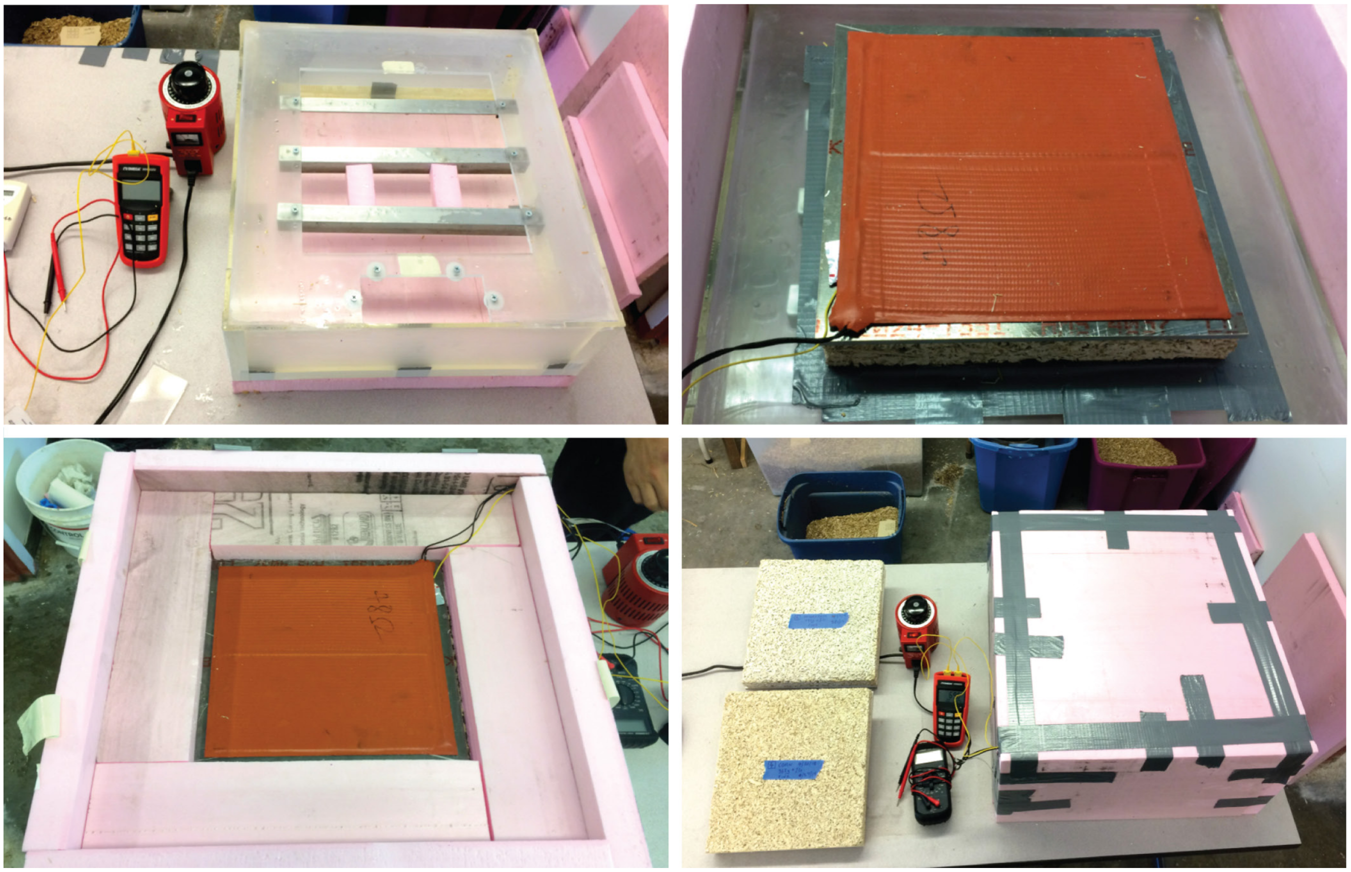

Figure 5. Thermal test set up. Taylor M.

Material	Test #	Conductivity K (W/mK)	Avg K	RSI per meter (mk/W)	Avg Rsi	R per inch (ft^2*f*h/BTU*in)	Avg R
Hemp Coarse	9	0.1290	0.1214	7.7518	8.2575	1.1215	1.1946
	15	0.1206		8.2932		1.1998	
	21	0.1146		8.7273		1.2626	
Hemp Fine	6	0.1228	0.1167	8.1456	8.6005	1.1784	1.2442
	12	0.1209		8.2686		1.1962	
	18	0.1065		9.3874		1.3581	
Corn Coarse	4	0.1110	0.1089	9.0069	9.1874	1.3030	1.3291
	10	0.1095		9.1299		1.3208	
	16	0.1061		9.4252		1.3635	
Corn Fine	7	0.1091	0.1080	9.1669	9.2610	1.3262	1.3398
	13	0.1087		9.2033		1.3314	
	19	0.1062		9.4129		1.3618	
Miscanthus Coarse	5	0.1101	0.1108	9.0807	9.0397	1.3137	1.3078
	11	0.1164		8.5885		1.2425	
	17	0.1058		9.4499		1.3671	
Miscanthus Fine	8	0.1134	0.1111	8.8203	9.0016	1.2760	1.3023
	14	0.1104		9.0547		1.3099	
	20	0.1095		9.1299		1.3208	

Figure 6. Thermal numbers. Taylor M.

Figure 7. Shed previous condition. Taylor M.

Figure 8. Shed in renovation process. Taylor M.

for potential concern. For Hemp and Miscanthus the range is from 19 to 24% while in Corn Stover it only accounts for 6.34%. What Corn Stover lacks in Lignin it makes up in Extractables that account for 17% as opposed to only 0.3 – 4% for Miscanthus and Hemp. The final component Ash ranges from 1% for Hemp, 3% for Miscanthus and 4% for Corn Stover.

This research was started before the 2018 United States Farm Bill removed industrial hemp, with THC content of less than 0.3%, from the list of Schedule 1 controlled substances, thus making it an ordinary agricultural commodity again, as it was in the 1950's. However, with the new interest in growing hemp since the 2018 Farm Bill became law producers have run into issues in how to harvest and more critically process the different components of the hemp plant for different uses. For our research we had to import our hemp from Europe where large processing plants have long been established. That said the harvesting methods we used to collect our corn stover and miscanthus fiber used machines readily available to any arable farmer.

Following the rehabilitation of the shed a larger installation will take place in the wall of a pole-barn with 12' tall walls where ongoing research is taking place into plants that can be used for biofuels or other rapidly renewable resources.

This prescient research has value both in developed and developing world contexts. As urban centers expand the ability to source rapidly renewable locally sourced building material could provide a valuable highly productive agro-industry that is less demanding on the environment than mining raw materials or being reliant on materials derived from petrochemicals.

ENDNOTES

1. Brosse, Nicolas, et al. "Miscanthus: a Fast-Growing Crop for Biofuels and Chemicals Production." Biofuels, Bioproducts and Biorefining 6, no. 5 (2012): 580–98. https://doi.org/10.1002/bbb.1353.
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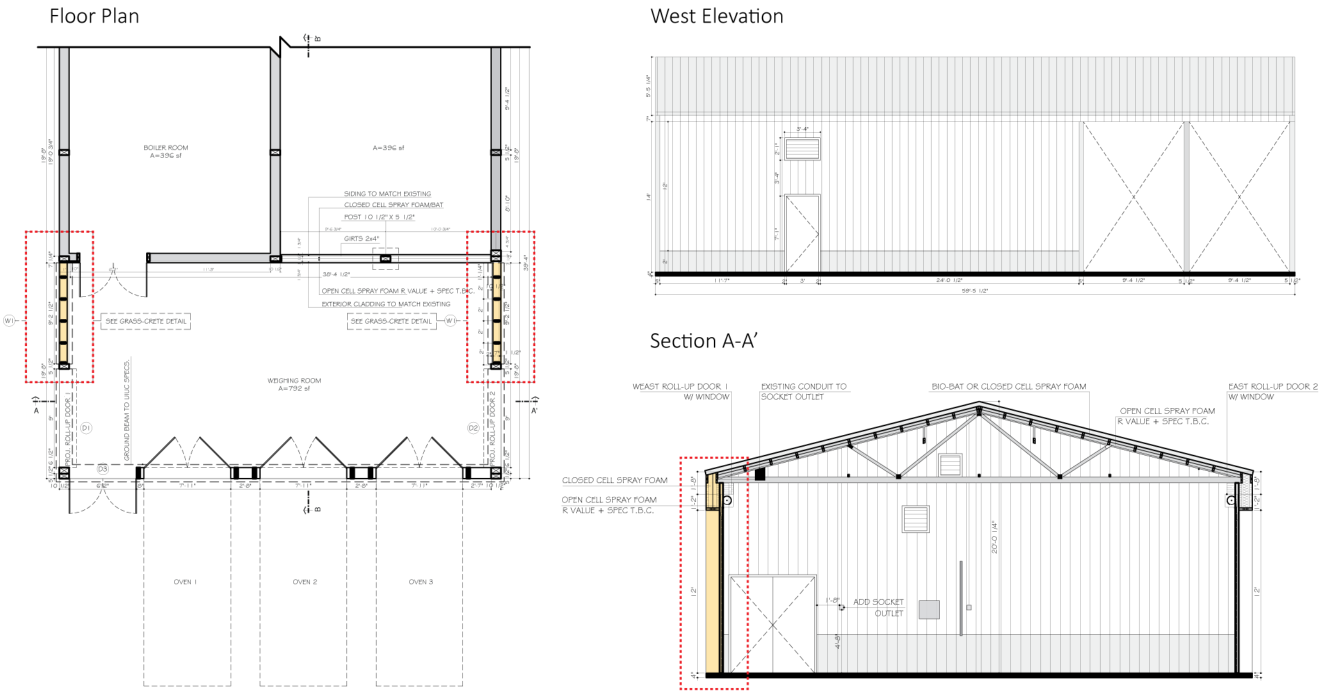

Figure 9. Weigh Station Renovation Proposal with Grasscrete walls. Flores F.

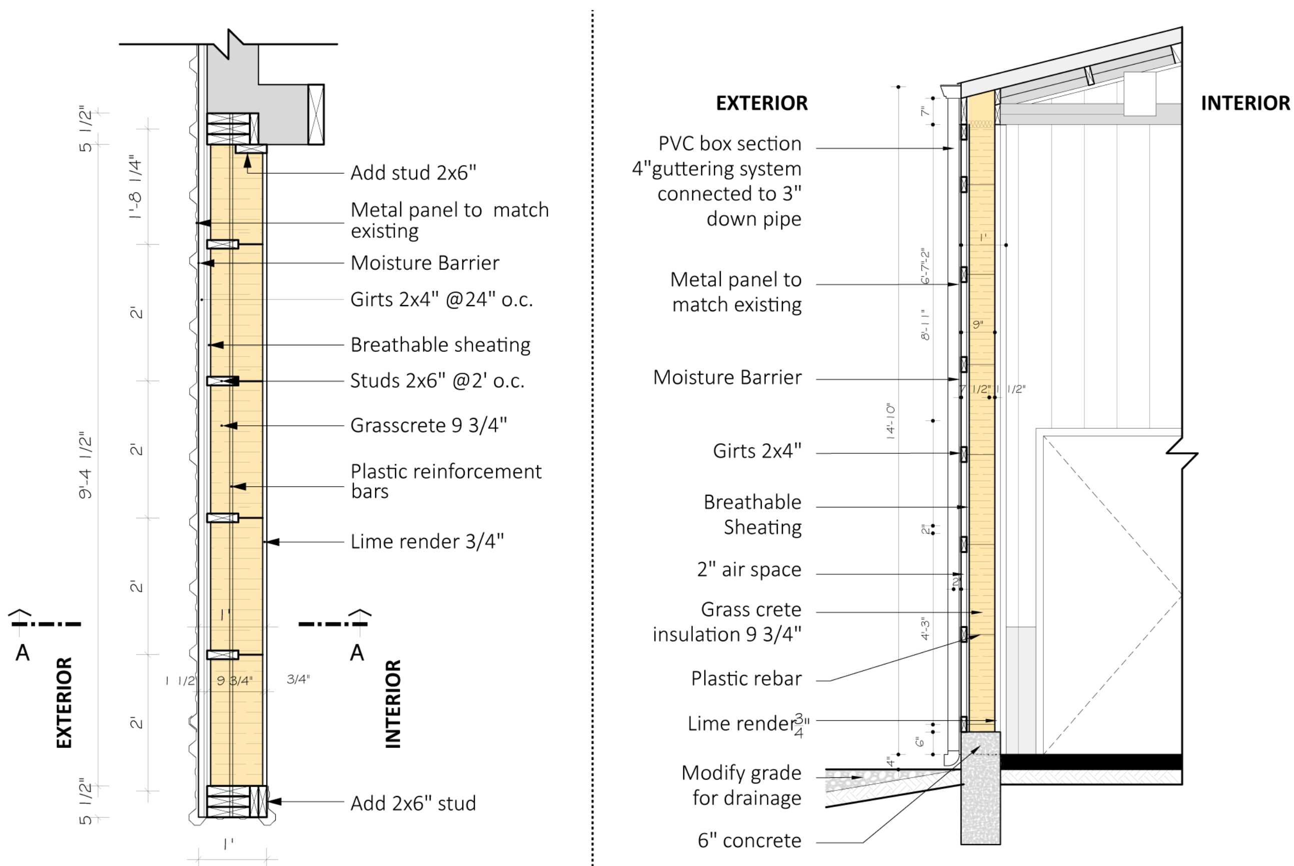

Figure 10. Grass-crete detail: plan view (left image) & section view (right image). Flores F.