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Accelerated Insulation Recycling System (AIRS)

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Evaluating Cotton Waste as an Alternative Thermal Insulation Solution

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ABSTRACT

The technical challenge addressed by this project is the curtailment of demolition and deconstruction waste associated with disposal of current insulation technologies. Construction and demolition waste accounts for 52 % of the total landfilled space (EPA, 2009).
Our objective is to develop a structurally sound insulation material with decreased thermal conductivity that can be easily disassembled and reused. A Design for Disassembly (DfD) approach is taken to address this challenge, and an alternative insulation system is proposed for assessment. The proposed system utilizes the structure of pre-fabrication panels to employ an insulation system with complimenting manufacturing and disassembly processes to optimize the ability to reuse the proposed material in its totality with minor reprocessing required.

INTRODUCTION

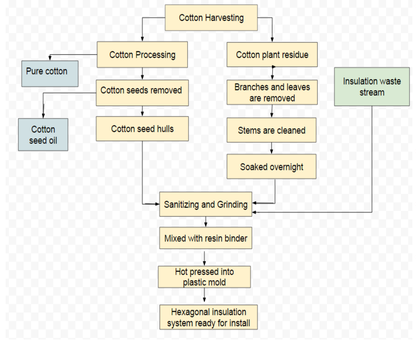
Many advances in disassembly sequencing in buildings have been proposed to recycle concrete, steel, and tile associated with construction and demolition waste, disposal of the insulation contained within every building persists as a significant environmental challenge.

Traditionally, the most common type of insulation utilized in buildings are mineral wool, expanded polystyrene (EPS), extruded polystyrene (XPS), cellulose, cork and polyurethane (Jelle, 2011). Mineral wool is typically utilized in frame homes and other structures where there are cavities that need to be filled. Expanded polyurethane is used commonly as an expanding foam on job sites to fill cavities between frames and to seal structures together, as it serves the dual purpose of insulation and adhesive.

Great strides have been made in improving heat conductivity metrics in these traditional insulations, and in the development of new technologies such as vacuum insulation panels. The sheer volume of insulation material, however, as well as variances in material composition, makes efficient reuse and recycling difficult. In fact, a survey of three insulation manufacturers revealed that they used little to no reclaimed insulation materials. In order to address the significant environmental challenge of curtailing waste associated with current insulation techniques, this research aims to (1) explore insulation design measures that will significant reduce the amount of landfilled insulation waste, while improving or sustaining key metrics (i.e., structural strength, thermal conductivity); (2) evaluate the design alternative in terms of environmental cost, effectiveness of thermal resistance and efficiency of design for disassembly.

METHODS

The proposed system utilizes these concepts and the standard structure of pre-fabrication panels to employ an insulation system with complimenting manufacturing and disassembly processes to optimize the ability to reuse the proposed material in its totality with minor reprocessing required. After cotton is harvested in the field, the main cotton crop is collected and further processed for industrial use. Left behind is cotton plant residue that is typically discarded or used in a mix as fertilizer. This cotton plant residue consists primarily of cotton stalks will be gathered for the insulation material production. A secondary cotton waste byproduct that will be utilized in this project is cotton husks. These two agricultural byproducts along with cement mortar comprise the raw materials.



Methods for redesigned insulation assembly

- To begin, leaves and branches are removed and the cotton stalks. Cotton stems are chipped and screened to an average size for the preparation of the cotton stalk fibers.
- Cotton husks are collected and torn down to small pieces.
- Cement mortar are mixed with the other two raw materials.
- Mixtures are cast in production molds and cured.

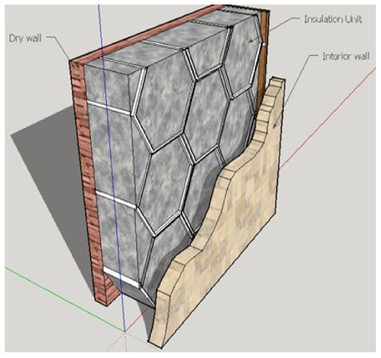
METHODS

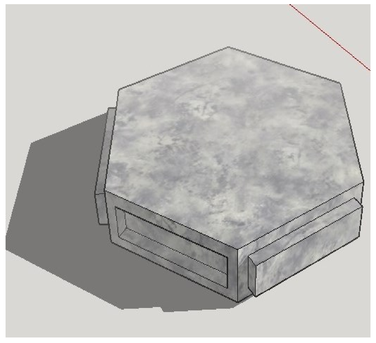
Samples prepared with different raw materials proportion are tested for their insulative properties.

Sample	Mortar (lb.)	Cotton husk (lb.)	Cotton Stalks (lb.)
1	1	0	0
2	0.106	0	0.102
3	0.313	0.011	0.042
4	0.298	0.024	0.026

Composition of each prepared sample

Waste cotton seed stalk (ICAC, 2015) and cotton seed hulls (Argrigold, 2014)



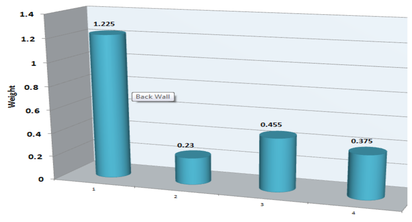


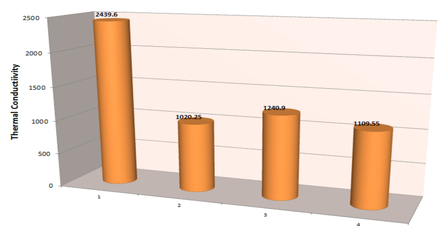
Graphical representations of hexagonal insulation unit

EXPERIMENTAL RESULTS

Extensive testing is needed to determine the most effective mix of raw materials to yield the most thermally insulative unit. Preliminary testing results indicate the following:

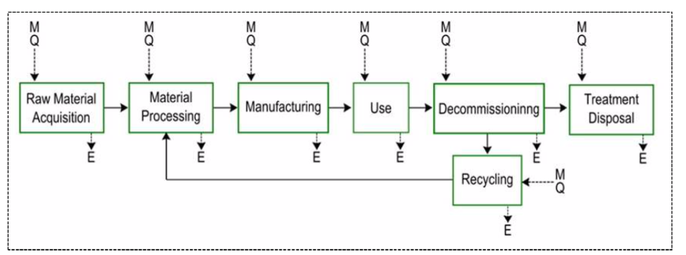
- The use of cotton husks and cotton stalks has shown significant decrease in thermal conductivity, proving its effectiveness as an insulator.
- The use of cotton stalks seem to be preferable as an insulator to cotton husks.
- The weight of developed insulation materials are relatively light, and allows for increased disassembly efficiency.



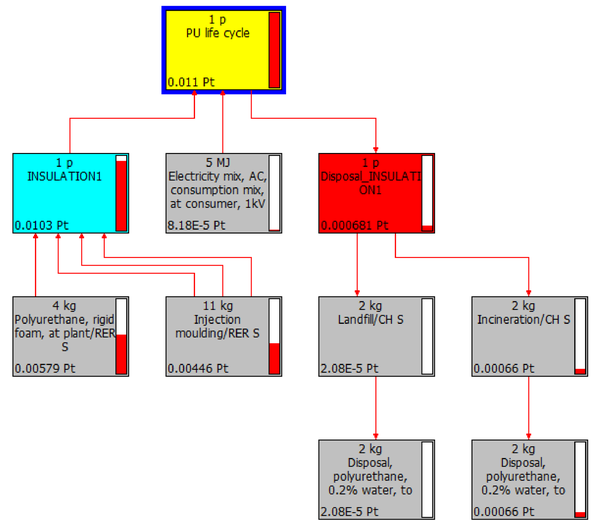


LIFE CYCLE ASSESSMENT

The second contribution of this project is a comprehensive life cycle inventory and assessment performed on the traditional and redesigned insulation. This work aims to produce a comprehensive inventory of life cycle data, and will quantify the emissions into the air, water, and land that take place through every life cycle phase associated with the traditional and redesigned insulation, as well as the potential for negative health effects associated with the production, use and end-of-life of each option.
Data gathering and analysis for this objective is still ongoing.
Systems boundaries and preliminary mapping of the inventory of the baseline foam case is shown below:



Life Cycle Assessment System Boundaries



Graphical representation of the baseline (polyurethane foam) insulation life cycle

CONCLUSION

This project is an ongoing study. The proposed alternative insulation is still being functionally tested, and life cycle assessment of developed technology is being performed.
The results deducted from progress so far indicates that the developed material has better insulative properties and is more light-weight than traditional insulation. Employing a 'Design for Disassembly' approach also holds promise for the developed material to be reused and recycled efficiently in pre-fabricated structures, significantly curtailing the deconstruction waste stream. Future research will involve completion of the life cycle assessment, structural testing and a disassembly efficiency evaluation.