therma-Q:
Analyzing the thermal performance of a quercus suber insulation.

introduction:

Rigid foam insulation is a well-known, and highly used, construction material. It is used for both roofs and walls of buildings and houses. It plays a big role in energy efficiency due to its thermal performance. However, despite its valuable role in construction and energy efficiency, its role in the environment leaves a lot to be desired.

Rigid insulation materials contain chemicals that contribute to ozone depletion, are not easily recyclable and have a high global warming potential (GWP), which means they add a lot of carbon to the atmosphere, contributing to climate change.

The goal of this project research is find an alternative insulation that can outperform the thermal properties of rigid foam insulation, resulting in energy savings, along with providing a highly sustainable, and eco-friendly product.

background:

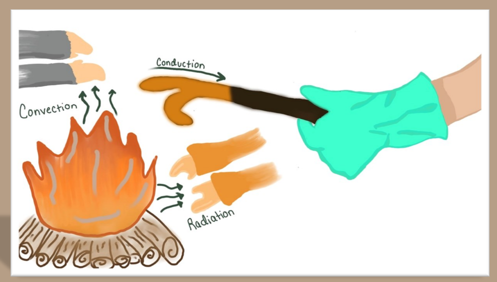
How does insulation work?
Insulation works by slowing down the heat transfer process.

Heat flows in three different ways: **conduction, convection and radiation.**

- Conduction is when heat moves through direct contact with a material.
- Convection is when heat moves through the air.
- Radiation is the transfer of thermal energy.

A product's insulation value, or **R-Value**, is dependent upon how it handles all three factors: it's determined by how heat conducts, convects, and radiates through a product.

The "R" in R-value stands for resistance. It refers to the resistance a material has to heat flow or temperature conduction. The higher the R-value of an insulation, the better it is.



Extruded Polystyrene Rigid Insulation (XPS)

- Manufacturing XPS Insulation involves combining polystyrene crystals with special additives and a gas blowing agent. All these materials get added into an extruding machine and are blended and melted into a thick liquid, then this liquid is made into foam.
- Made from HFCs (hydrofluorocarbons) which are greenhouse gasses that destroy the ozone layer.
- Made from non-renewable sources (petroleum and natural gas)
- The R-Value for XPS Insulation tested is 5.0 per inch.
- The blowing agents and gas bubbles used to make XPS lessen over time, which lessens the insulation value.
- XPS can cause condensation and mold problems with time.
- NOT fire resistant—emits toxic fumes when it catches fire.
- NOT termite resistant.

Expanded Polystyrene Rigid Insulation (EPS)

- Manufacturing EPS Insulation involves using raw polystyrene beads and expanding them to a certain size. They are then molded and steamed again so that the beads expand more until they form a solid block.
- Made from non-renewable sources (petroleum and natural gas)
- The R-Value for the EPS Insulation tested is 6.0 per inch.
- NOT fire resistant—emits toxic fumes when it catches fire.
- NOT termite resistant.

Q Rigid Insulation (Quercus Suber a.k.a. "Cork")

- Made from the bark of a cork oak tree. The bark is harvested and cut into small granules or powders. It is then put under high pressure with water and the natural resins of the cork bind together.
- Typical R-Value approximately 3.6 to 4.2 per inch.
- Has more water resistance than other insulators
- Excellent soundproofing material.
- Fire resistant-NO toxic gasses if ignited.
- Termite resistant.

variables:

Independent Variables:
Rigid insulation material (XPS; EPS and Q)
Exterior Temperatures and Data Collection Times

Dependent Variables: Interior Temperature of hypothetical house.

Controlled Variables: Construction of hypothetical house; testing environment-placement and position ; insulation thickness

problem:

Can a quercus suber insulation outperform the traditional, rigid insulation commonly used in building construction?

hypothesis:

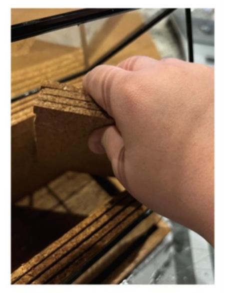
If a quercus suber (cork) composite insulation is devised and compared against a rigid board insulation of the same thickness, then the quercus suber composite insulation will thermally outperform the rigid insulation, resulting in a safer, eco-friendly, sustainable and superior energy savings building material.

procedure:

Project Setup:

1. Using masking tape and marker, label each thermometer reader and sensor with following:
   - The first with "EPS",
   - The second with "XPS"
   - The third with a "Q".
   - The fourth thermometer will not be labeled—this will measure the outdoor temperature.

2. Take each layer of cork wall tile and using hot glue, glue to a second layer of cork. Repeat this layering until you get a 1" thick cork board thickness. Four boards glued together will make a 1" thick board.
3. Preparing the insulated houses: Measure and cut each board (EPS, XPS and Q) so that insulation covers all glass surfaces of the terrarium, or the "hypothetical house". *Note: Cutting these boards requires assistance from an adult.* All pieces of insulation should fit snug against the glass and up against each other.



4. Using foam glue, seal all gaps between the layers of rigid board insulation (EPS and XPS).
5. Using hot glue, seal all gaps between the layers of cork board insulation (Q).
6. Place the thermometer sensor inside each hypothetical house and leave the digital reader outside.

Testing (Cold Day):

7. Place all houses in a location outdoors, on top of a table or other sturdy surface. Keep the houses about one foot apart so that the house shadows created by the sun don't fall on any of the other houses.
8. Record temperatures for all 4 thermometers, every three hours (at the same time each day), for a minimum of 5 temperature readings per day.
9. Repeat this for ten days.

Testing (Hot Day-Simulation):

10. Preheat oven to the lowest temperature setting possible (170 °F).
11. Once preheated, turn the oven off, then place the external thermometer sensor in the middle of the oven rack on a cookie sheet and close the door.
12. Open the oven door for a few seconds at a time until the temperature display for the sensor in the oven reads +/-120 °F.
13. Place the frozen ice packs inside each house along with each sensor *(this simulates air conditioning inside the house on a hot summer day).*
14. Place the three houses in the middle of the oven to join the fourth temperature sensor already inside . Close oven door.
15. Begin to record the temperatures for the hypothetical houses and the fourth sensor when temperature is close to105 °F.
16. Open the oven door for 2 seconds, then close the door immediately to consistently drop the temperature inside the oven and continue recording the temperature for all sensors as the temperature inside the oven lowers.
17. Repeat procedure steps #10 thru #16 ten separate times to simulate ten separate hot days. Each simulated day should have a minimum of 5 readings.

*Note-Highest temperature setting in oven to simulate hottest day should be between 95°F-105°F.

data:

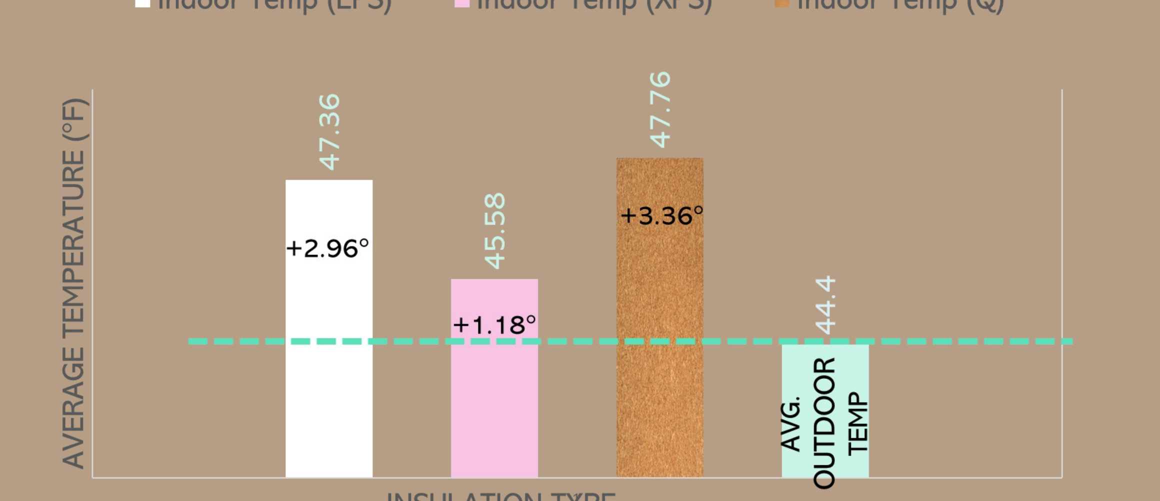
Day 3- Cold Day Sampling of Temperatures

Reading #	Outdoor Temp. (°F)	Indoor Temp. (°F) (EPS)	Indoor Temp. (°F) (XPS)	Indoor Temp. (°F) (Q)
3-1	29	32	31	32
3-2	44	47	45	48
3-3	54	56	55	57
3-4	55	58	56	58
3-5	43	46	44	47
DAY 3 AVG.	45	47.8	46.2	48.4

5 COLDEST DAY AVERAGE TEMPERATURES

READING #	Outdoor Temp. (°F)	Indoor Temp. (°F) (EPS)	Indoor Temp. (°F) (XPS)	Indoor Temp. (°F) (Q)
DAY 1 AVG.	46.2	49.4	47.4	49.6
DAY 2 AVG.	43.4	46.8	44.8	47
DAY 3 AVG.	45	47.8	46.2	48.4
DAY 4 AVG.	43	45.8	44	46.2
DAY 5 AVG.	44.4	47	45.5	47.6
AVERAGE	44.4	47.36	45.58	47.76

5 COLDEST DAY AVERAGE INDOOR TEMPERATURES



Tables and Charts created by Researcher (Microsoft Powerpoint)

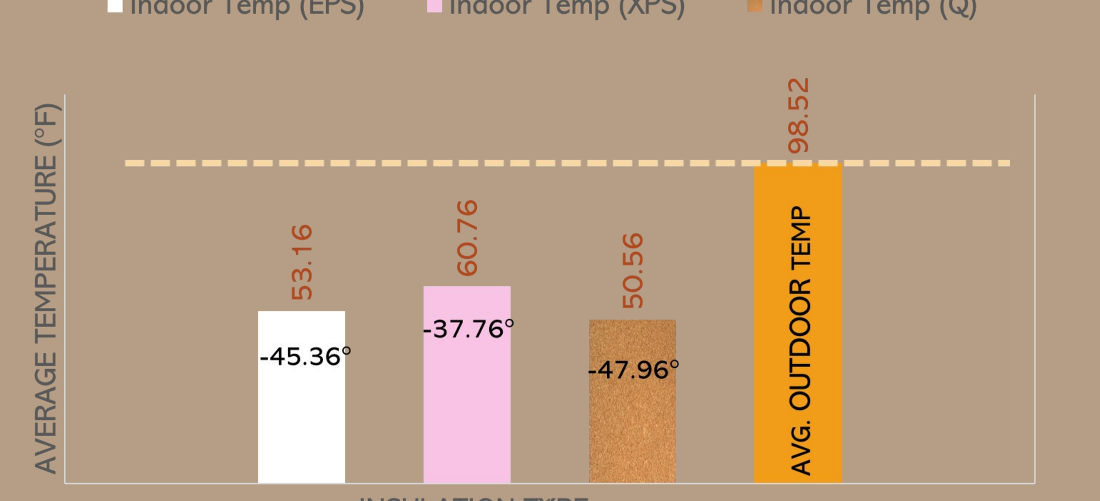
Day 1-Hot Day Sampling of Temperatures

Reading #	Outdoor Temp. (°F)	Indoor Temp. (°F) (EPS)	Indoor Temp. (°F) (XPS)	Indoor Temp. (°F) (Q)
1-1	101	54	59	51
1-2	100	53	59	50
1-3	99	52	59	50
1-4	98	52	59	50
1-5	96	50	59	49
DAY 1 AVG.	98.8	52.2	59	50

5 HOTTEST DAY AVERAGE TEMPERATURES

READING #	Outdoor Temp. (°F)	Indoor Temp. (°F) (EPS)	Indoor Temp. (°F) (XPS)	Indoor Temp. (°F) (Q)
DAY 1 AVG.	98.8	52.2	59	50
DAY 2 AVG.	99	53.4	61.2	50.8
DAY 3 AVG.	100	55	61.8	52.6
DAY 4 AVG.	99.8	54.2	61.6	51.8
DAY 5 AVG.	95	51	60.2	47.6
AVERAGE	98.52	53.16	60.76	50.56

5 HOTTEST DAY AVERAGE INDOOR TEMPERATURES



materials:

QTY	MATERIAL(S)
3	Glass terrariums (hypothetical houses)
4	Digital thermometers with wireless sensor
10	12"x 12"x1/4" cork wall tiles
As required	Hot glue sticks and glue gun
1 board	1" thick expanded polystyrene rigid board insulation (EPS)
1 board	1" thick extruded polystyrene rigid board insulation (XPS)
As required	Foam Glue
1	Cutting Tool and Replacement Blades
1	Ruler
1	Masking Tape
1	Marker
1 ea.	Lab Notebook, Pen & digital camera to record results
1	Traditional Oven (large enough to hold all three houses at once)
3	Small bead ice packs (frozen)
1	X-Large Cookie Sheet
1	Personal Protective Equipment (safety glasses, gloves, face mask, etc.)

results:

The results from this experiment proved that a quercus suber (cork) insulation can outperform the traditional, rigid insulation commonly found in building construction. The Researcher's hypothesis was correct. The data showed that the cork insulation consistently outperformed the expanded polystyrene insulation (EPS), and the extruded polystyrene insulation (XPS) in both scenarios. It kept the inside of the hypothetical house warmest when the outdoor temperature was cold, and it kept the inside of the hypothetical house cooler when the simulated outdoor temperature was hot.
When the outdoor temperature was cold, the cork and the EPS insulation indoor temperature were pretty even. In some cases, the cork was slightly better. But both outperformed XPS insulation. When the outdoor temperature was hot, the cork outperformed both the EPS and the XPS consistently. The EPS was about two to three degrees hotter than the cork, and the XPS was about nine to ten degrees hotter than the cork. The XPS was the poorest performer overall.

conclusion:

The findings of this experiment mean that by using a cork insulation material, it would take less energy to heat buildings in the colder months and less energy to cool buildings in the hotter months. The findings also mean that it would take less thickness of cork insulation to achieve the same thermal resistance as a thicker rigid insulation.

In addition to it's superior thermal performance as shown on this experiment, cork has many benefits that make it a better performing product to both EPS and XPS rigid board insulations:

- It is harvested from the bark of a living cork oak tree, which makes it a renewable and sustainable resource;
- It is biodegradable and recyclable into many different types of products.;
- Cork is fire-resistant;
- Cork is termite resistant;
- Cork is free of harmful toxins;
- Cork is tough: a cubic inch of cork can withstand up to 14,000 lbs of pressure without breaking.
- It is also a good sound isolator.

On a cellular level, cork looks like a honeycomb of air pockets, this is what makes it a great insulator. Each cell has 14 sides, and this makes the cell walls flexible, strong, waterproof and airtight. Making it a superior product to other rigid insulations.

Energy consumption, pollution, greenhouse gas emissions are all topics that we've all become very familiar with, because we see the effects they have on climate change. This graphic helps explain the importance of this study:

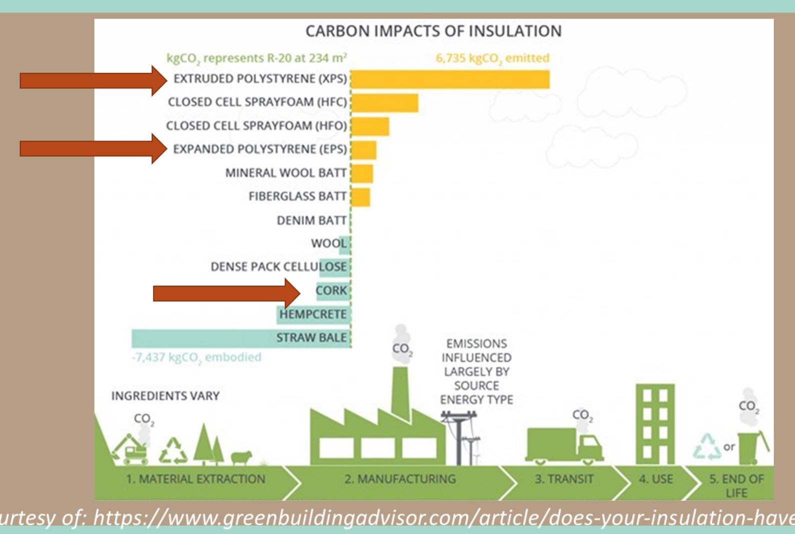


Image courtesy of: https://www.greenbuildingadvisor.com/article/does-your-insulation-have-low-embodied-carbon

When cork is harvested, and it regenerates itself, it absorbs CO2, which means that instead of hurting the environment, harvesting cork actually reverses the greenhouse gas emissions problem. It is carbon-negative.

The research associated with this project has the potential to create major societal impacts including: a reduction in energy demand and consumption, improvement of indoor thermal comfort and benefits to the environment.

After evaluating the results of this experiment, and researching this topic, it is the Researcher's opinion that further research of the Quercus suber (cork) material as an insulator will continue to produce positive results.

photo credits:

All photos, images and graphics were done or taken by the researcher or parent unless otherwise stated.