Using Gypsum to Reduce the Urban Heat Island Effect

Purpose

The purpose of this project is to use gypsum and an acrylic polymer emulsion to create a roofing treatment for shingles and test the effectiveness of the treatment. The objective is to decrease the maximum temperature attained and reduce the impacts of the urban heat island effect.

Introduction

Each year, more cities become urban heat islands. An urban heat island is known as a metropolitan area that is much warmer than the rural areas surrounding it. Urban heat islands are created in areas that have lots of people and activity. Due to urban heat islands, the air temperature in a city can be 1°C to 12°C higher than its rural surroundings.

Urban heat islands form when cities replace natural land covers such as trees, grass, and wetlands with pavement and buildings. Removing trees and vegetation eliminates the cooling effects of shade and evaporation of water from soil and plants. Pavement, rooftops, and other non-reflective surfaces absorb heat during the day and release it at night, which magnifies overnight temperatures. Due to the temperature being so high, many people use air conditioners, which release hydrofluorocarbons, and further increases the urban heat island effect.

The urban heat island effect also intensifies extreme hot weather which can cause breathing problems, heat strokes, and could lead to illness or death. Since temperatures continue to rise due to climate change, the urban areas are also more likely to experience more frequent and longer heatwaves.

Urban heat islands can also accelerate the chemical reaction that produces ground-level ozone or smog, which is formed when NOx (nitrogen oxides) and volatile organic compounds (VOCs) react in the presence of sunlight and hot weather.

Gypsum, which is also known as hydrated calcium sulfate, is a major rock-forming mineral that produces massive beds. Gypsum is formed when sulfur is present in water, bonds with oxygen to form a sulfate. The sulfate combines with calcium and water to form gypsum. Gypsum is usually white or colorless. It can also be translucent or transparent with vitreous luster. Minerals with vitreous luster have reflective properties that are similar to glass. Due to the chemical composition of gypsum, it is an excellent non-toxic fire retardant. Gypsum also has a high albedo, which makes it more reflective. Gypsum is widely available and is one of the least expensive yet most useful minerals to be used in building materials.

Acrylic polymer emulsions are used in industries such as adhesives, textiles, and specialty coatings. Emulsions are a mixture of two or more liquids that are generally not mixable. Emulsions do not exhibit a static structure, as they are liquids. Acrylic polymer emulsions specifically deal with the synthetic side of polymers.

Acrylic resins are a group of thermoplastic substances. Methyl methacrylate combined with an acrylate is the specific acrylic resin that was used. Acrylic resins are also considered to be extremely waterproof.

Hypothesis

The first hypothesis is that the higher the ratio of gypsum to acrylic polymer emulsion, the more effective it will be at decreasing the heat absorbed because gypsum contains properties such as a vitreous luster and a high albedo that aids in reflecting the heat whereas the acrylic polymer emulsion does not. The second hypothesis is that the treated shingles will help to maintain the original temperature on the inside of the Styrofoam container because the heat is not being absorbed.

Results

Phase I

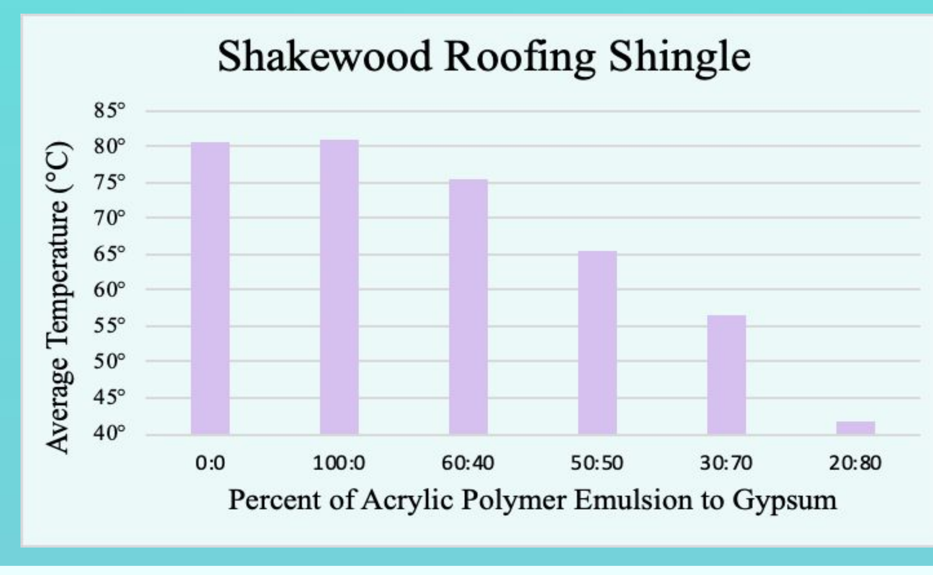

Figure 1: Graph of the Average Temperature Change of the Shakewood Roofing Shingle

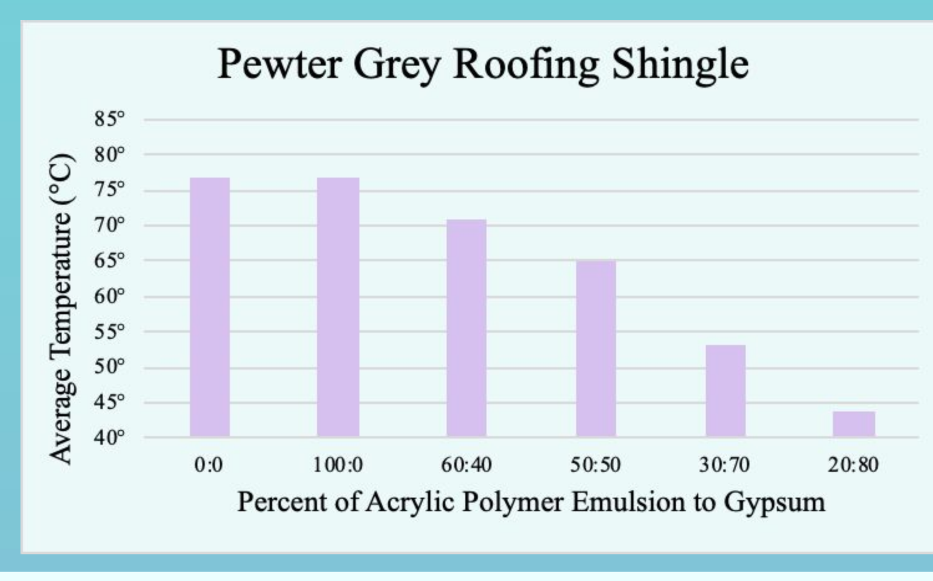

Figure 2: Graph of the Average Temperature Change of the Pewter Gray Roofing Shingle

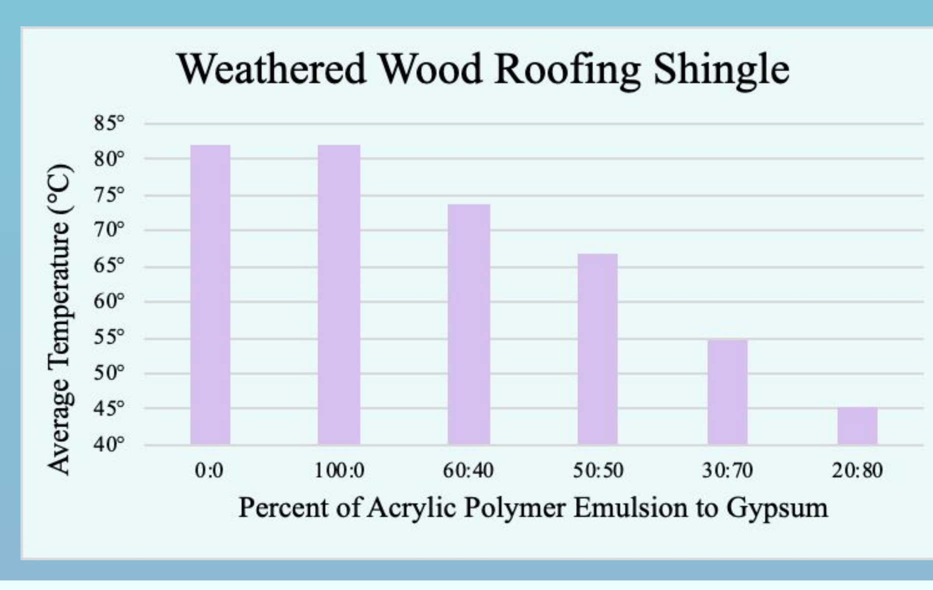

Figure 3: Graph of the Average Temperature Change of the Weathered Wood Roofing Shingle

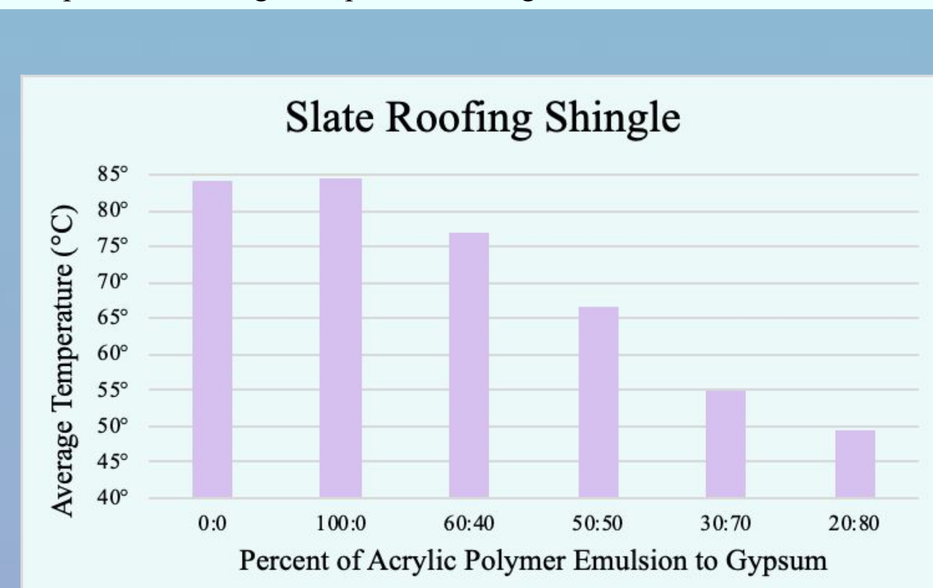

Figure 4: Graph of the Average Temperature Change of the Slate Roofing Shingle

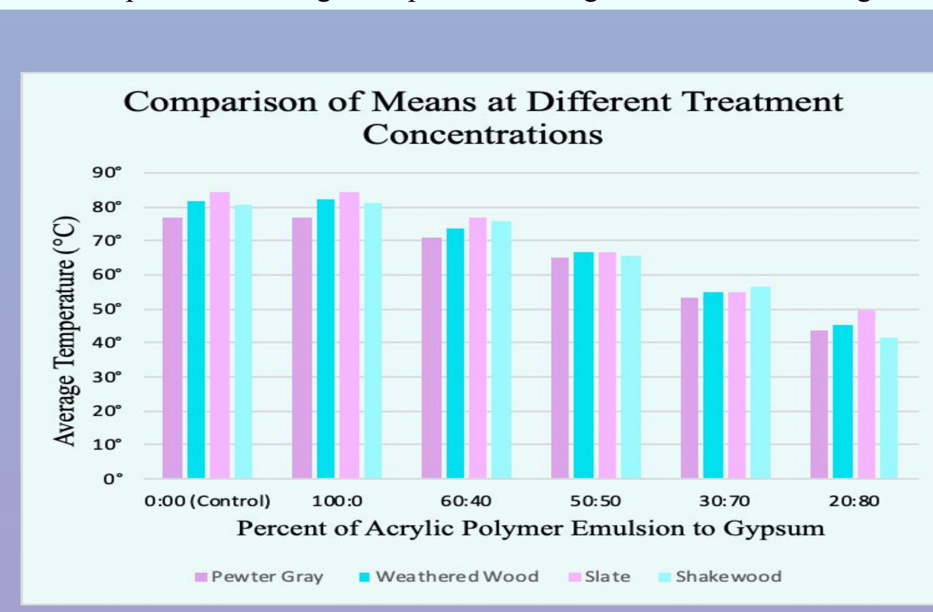

Figure 5: Graph of Statistical Analysis (ANOVA)

Phase II

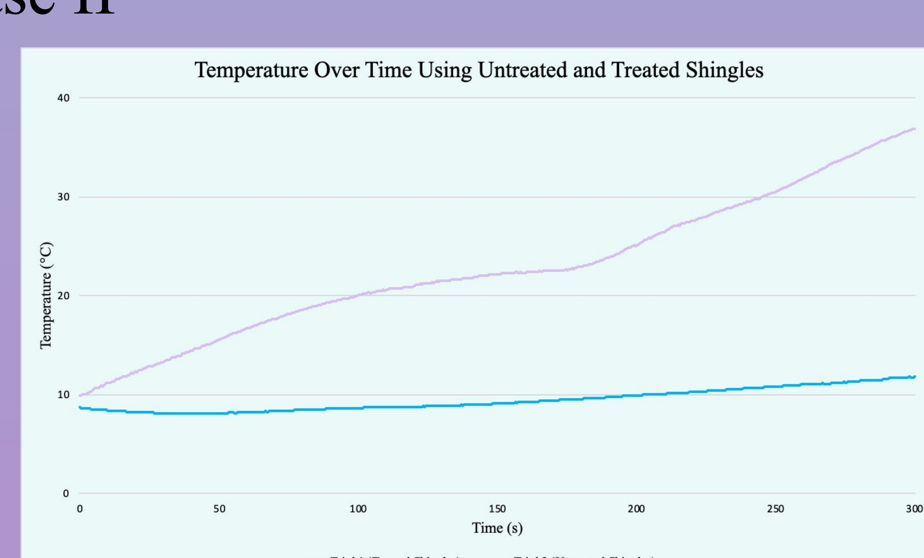

Figure 6: Graph of the Temperature of the Inside of the Styrofoam Containers

Methodology

Phase I: Testing Different Concentrations

Gather four different colored shingles and cut each of them up into six small rectangles measured 5.08 cm by 5.08 cm. The ratios for each mixture are 0 g (0%) of gypsum to 0 mL (0%) of acrylic, 0 g (0%) of gypsum to 40 mL (100%) of acrylic, 16 g (40%) of gypsum to 24 mL (60%) of acrylic, 20 g (50%) of gypsum to 20 mL (50%) of acrylic, 28 g (70%) of gypsum to 12 mL (30%) of acrylic, and 32 g (80%) of gypsum to 8 mL (20%) of acrylic. Place five metal bowls in a line and label the outside of the bowls with the correct mixture. Weigh the necessary amount of gypsum and acrylic polymer emulsion according to each ratio and place it in the bowl labeled with the correct mixture. Attach each popsicle stick that corresponds with the mixture being mixed to the end of a drill and stir each mixture for five minutes. Gather five small paint rollers and use each roller to apply each mixture to the four different colored shingles until all of the shingles have been treated except for four of different colored shingles that will be used as a control. Allow the shingles to dry indoors for 24 hours. Place a square piece of cardboard over the testing surface and set three metal stands around the cardboard. Clamp a 150-Watt Aluminum Light Fixture to each stand for all of the three stands. Screw two 75-Watt A19 Spiral CFL Daylight Light Bulbs into each of the two 150-Watt Aluminum Light Fixtures and a 75-Watt A19 Non-Dimmable LED Daylight Light Bulb into the other 150-Watt Aluminum Light Fixture. Place one of the shingles in the middle of the cardboard. Set a timer for ten minutes and turn on the light fixtures when the timer starts. After ten minutes, use an infrared thermometer laser temperature gun and point it at the shingle to get a temperature reading of the surface of the single. Record the reading in a table and turn off the light fixtures. Replace the shingle with a different one until all of the shingles have been tested. Continue until there is three trials per mixture for each color of the shingles.

Phase II: Testing Insulation

Gather two 1.42 liter round styrofoam containers. Take the lids off of the containers and replace the lids with shingles. Make sure one container has treated shingles and the other has untreated shingles. Label each container to distinguish which has treated shingles and which does not have treated shingles. Place both in a freezer at -18 degrees Celsius for 24 hours. After 24 hours take the boxes out of the freezer. Place both of the boxes under the same apparatus used in the first procedure. Place a temperature sensor in each of the boxes and turn on the light fixtures and LabQuest for 5 minutes. After 5 minutes, analyze the graph that was produced on the LabQuest.

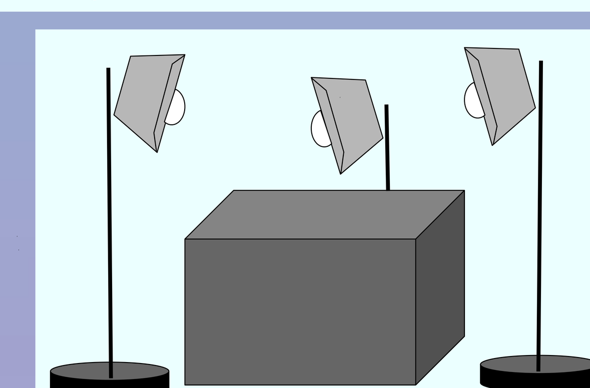

Figure 7: Diagram of Apparatus

Conclusion

Both of the hypotheses were supported, and the higher ratio of gypsum to acrylic polymer emulsion, 80% gypsum to 20% acrylic polymer emulsion, was the most effective at decreasing the heat absorbed by the shingles. It also shows the potential to be effective at reducing the urban heat island effect. The lower ratios of gypsum to acrylic polymer emulsion lowered the temperature of the roofing shingles, but not as significantly. Overall, all of the ratios with gypsum in them could be used. In the future, other minerals could be studied in order to make this treatment more accessible in developing countries.