Heat Islands
Aggregate Size Analysis

By: James Horne

Question:

How does the different size of coarse aggregate in concrete affect the heat absorption in concrete?

Goal:

My goal for this experiment is to find the right size of coarse aggregate in concrete to help prevent the major issue of the heat island effect in urban areas.

Hypothesis:

If I heat multiple concrete samples that have different sizes of coarse aggregate then the sample with the largest sized aggregate will absorb the most heat because larger sized objects can store more energy.

Project Setup:

I tested 5 different types of concrete samples over a 60 minute time period (30 minutes heating, 30 minutes cooling). Using a laser thermometer in a controlled environment (laboratory) I recorded the temperature of the samples in 9 different areas every 5 minutes.

Testing Procedure:

1. Collect the following materials for the experiment. (see materials list)

2. With each concrete sample do the following:
   a) Put the concrete sample up vertically on one side of the table/lab bench. Then add a white piece of paper behind the concrete sample supported by retort stands for clear thermal imaging.
   b) Attach the heatlamp to the retort stand one foot away from the confrete sample. Place a heat lamp in front of the concrete sample.
   c) Set thermal camera to monitor the temperature of the concrete.
3. Turn on the heat lamp.
4. For 30 minutes every 5 minutes record the temperature of those 9 areas on the sample.
5. Turn off the heat lamp.
6. For 30 minutes every 5 minutes record the temperature of those 9 areas on the sample.
7. Repeat steps 2-4 for the other concrete samples.

Materials:

- Thermal camera
- 5 concrete samples with different amounts of coarse aggregate inside of it.
- Heat lamp
- Table/surface to test on
- Paper (white) – 50cm x 40cm
- 3 retort stands
- Stopwatch
- Infrared laser thermometer

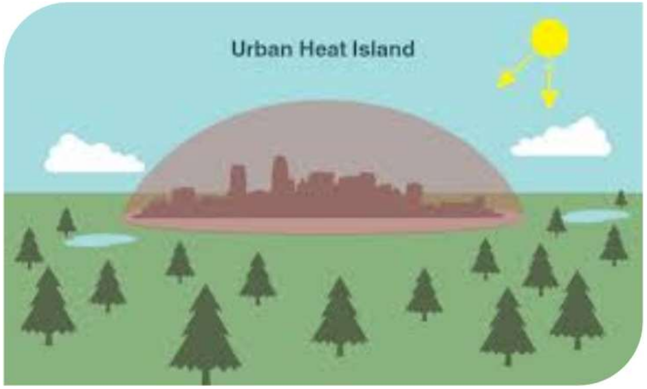
Variables:

Manipulated *What I changed*	· The size of coarse aggregate in each testing sample.
Responding What I watch for or measure	· The effects how different sizes of coarse aggregate effects heat absorption in concrete
Controlled *What stays the same*	· Same surface that the experiment was tested on (lab bench) · Same heat lamp · Same setting that the lamp is on · Same lab room. · Room temperature (20 degrees Celsius) · Same altitude · Length of the experiment per trial (30min) · Same Day I tested all samples on · Same person doing the experiment (Me) · Same laser thermometer to capture the temperature of the concrete

Reaserch

<u>What are heat islands?</u>

Heat islands are areas of land that are of higher temperature compared to the areas surrounding. An example of this is in the downtown streets of New York. In this large city temperatures can get up to 3°C hotter than the surrounding areas. The high amounts of concrete in these areas contribute to the high temperatures. Concrete adds to this issue by absorbing up to 95% of the energy coming from the sun. The thing that causes these abnormal temperatures has to do with the lack of plants and abundance of concrete in the area. Plants help this issue by releasing water vapor into air practically acting like an AC unit. Plants also absorb heat. Heat islands are a very large issue around the world.



<u>How are heat islands impacting Calgary?</u>

Heat islands are affecting places all around the world. But how is it affecting Calgary? There are areas in Calgary that are way hotter than the surrounding area. For example in Nose Hill the temperature is about 1-2 degrees Celsius cooler than downtown Calgary. And in rural areas it's usually 2-3 degrees cooler than Calgary.

Calgary is a growing city and with this comes more developments. An example of this is the Cowboys Park where there is a plan to take away 70% of the greenspace there and replace it with concrete. The plan of this is so they can support larger venues when the stampede rolls around. There's a lot of issues with this first of all they're taking away greenspace in Calgary from Calgarians. Not only that but its adding to the heat island effect.

What do heat islands affect? What are the consequences?

With the increase of tempertures there are terrible consequences. Some consequences include the health of human citizens and impacts to wildlife.

First of all this could impact the health of citizens in the city. With increased temperatures to nearly 4°C this could be a very serious threat for the wellbeing of our community. We already had a record breaking summer. Imagine if it was hotter. What would happen to citizens that can't afford cooling units? Such as AC or even just a fan. It could affect our wellbeing.

Heat islands can become very deadly when the temperature is not controlled. One way that is not direct is when areas affected by heat islands become a lot hotter. There is a lot more energy needed to cool the buildings. Meaning people will need to burn more fossil fuels to cool their homes. With the increased prices it's estimated to rise up to 5% per year. The effects of fossil fuels on the environment are extravagant. Fossil fuels release CO 2, a greenhouse gas. A greenhouse gas is any gas that traps heat inside the earth's atmosphere. With all the extra heat it can cause a variety of problems. Some of these problems include the melting of the ice caps which lead to immense flooding and other natural disasters like tornados and increased drought. This can affect entire ecosystems and even how our crops grow. If we don't fix this problem now there can be increased mortality in the future.

Also, with increased temperature there will be some environmental issues. For example with a slight change in temperature there could be a lot of behavioral changes that could occur to animals. An example of this may include a flock of Canadian geese migrating late. With the separate microclimate the geese can't find the right time to leave. So they are a couple weeks off. This also may continue to add on every year because they may stay down south longer creating a loop of poorly timed migrations. But with these poorly timed migrations this could lead to late breeding seasons putting the entire species on the line. This may not only affect the behaviors of birds but every type of living animal on this planet. From insect to amphibian it could be a catastrophe.

How do heat islands affect our health?

Heat islands can be very harmful to our human health. Not only can it harm our health it can also lead to deaths. Heat islands also are able to give people heat strokes and possible discomfort. Heat stroke is a common condition from the body overheating. It leads to possible discomfort and even over exhaustion. Heat strokes already cause over 1,300 deaths per year worldwide. I wonder how this number will grow in the future. And with the heat island effect it could only get worse from here.

What causes heat islands?

The culprit of this issue is concrete. Concrete absorbs up to 95% of the sun's energy. This is because of concretes thermal mass meaning the capability’s to absorb and allow heat to flow through it. Once it is absorbed it then is radiated out to the areas around causing these areas to become hotter eventually causing a wide variety of problems. If we could reflect the sun's energy back out into the atmosphere then the areas would become a lot less hot. Some cities are trying to solve this problem by making their sidewalks lighter in shades of grey to help reduce the amount of the sun's energy absorbed. Lighter colors absorb less heat because of its ability to reflect more light.

What is Heat?

Encyclopedia Britannica defines heat as, “energy that is transferred from one body to another as the result of a difference in temperature.”

Cambridge Dictionary defines heat as “the quality of being hot or warm, or the temperature of something."

What is temperature?

The measurement of hotness or coldness described in terms of many scales like Celsius, kelvin, or Fahrenheit. It's also known as the way to measure the transfer of energy or heat. For my experiment I measured using the Celsius scale.

How do you measure temperature?

You can measure temperature in many different ways.

First off all examples are the standard glass thermometers or using a less common laser thermometer.

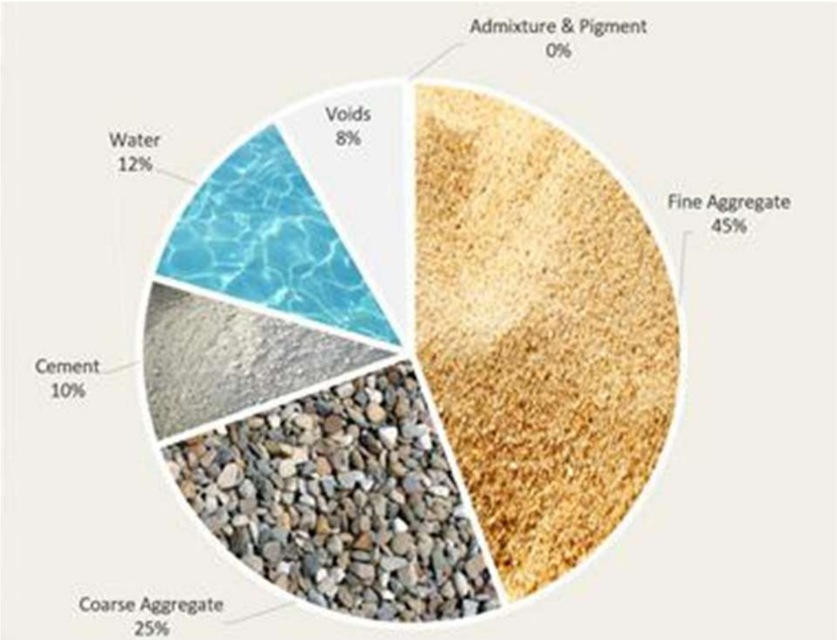
When measuring temperature we use 3 main scales Fahrenheit, Celsius, and finally Kelvin. Celsius and Kelvin are very much alike in that in both scales the freezing and melting point of water are both 100° apart. Also Kelvin's scale starts at absolute zero while Celsius starts at the freezing point of water. Fahrenheit is unalike from both scales putting 212°F as water's boiling point and 32°F as water's freezing point. Even though all scales are different they are used all around the world. While testing my experiment I used a laser thermometer to measure the temperature of the concrete. Plus it has very accurate readings and it’s very easy to use.

History of heat islands.

Heat islands have been in our cities for centuries but the effects of them are becoming a large-scale issue in the past decade. Even cities like ancient Rome also tried to tackle this issue. Because of Rome's fast growing city there was an urge for densification causing the city to become hotter. To solve this problem some architects started to paint the sides of their walls white to prevent the heat from absorbing into the structure. This helped reduce the temperature in Rome a lot because of the heat getting reflected away from the buildings.

What makes up concrete?

Concrete is used in all types of construction. The reason why it is used so much is it is a cheap reliable source of making practically every structure on the planet. What makes it cheap is it's made up of cement, aggregates and a little bit of water which are all inexpensive and available materials.



<u>What makes up cement?</u>

Cement is made by getting crushed limestone mixed with sand mixed in with ground clay, shale, iron ore, fly ash, and alternative raw materials. Depending on the company's procedure on making cement the amounts of these materials recipe can vary.

<u>History of concrete:</u>

Concrete and cement date back to the roman times when cement was made to make all sorts of structures. From the colosseum to the the Pantheon Dome cement was everywhere. To make this cement they used volcanic ash to react with water so slowly harden into cement. It was revolutionary so when the fall of the Roman Empire happened all the recipes and how to make it were lost. But into the middle and dark ages. But in 1756 John Smeaton created something called Portland cement which was a wild success around Europe and around the globe. But as time went on more scientists looked into cement and developed concrete. Which was a mixture of cement aggregates and water. Then in the 20^{th} century different types of concrete were made. Which brings us to today where concrete is used all over the place and is everywhere.

<u>How and why does concrete absorb heat?</u>

Concrete absorbs heat due to something called thermal mass. Thermal mass is the ability to absorb store and have energy pass through it. Because concrete is a very dense material its thermal mass is very high. Meaning that it can absorb and store heat very easily.

Types of concrete: Reinforced, Restressed, Precast, Masonry, Air Entrained

Reinforced Concrete:
Is made by casting concrete around steel rods as well as bars. It then dry's around these rods to form strong concrete used supports in large buildings like condos or skyscrapers.

Restressed Concrete
Commonly made by casting concrete around steel cables stretched by hydraulic jacks. The steal helps strengthen the concrete and when stretched its even stronger. This kind of concrete is used in making bridges and other supports because of its ability to resist most forces.

Precast Concrete
Concrete that is already precast and hardened before used for construction. Recasting firms make this concrete for sewer pipes, floor and roof units, wall panels and even beams.

Concrete Masonry
Includes many shapes and sizes of precast block. It is used to make 66% of all the masonry in the United States of America. Some is decorative and some resembles brick.

Air Entrained concrete
Contains billions of air cells in each cubic foot of the concrete . These cells are formed by adding soap like resinous or fatty materials to the cement to the concrete when mixed. Cells give the water in the concrete enough room to expand and freeze. They also protect the surface of the concrete from chemicals used to melt ice. (Ice milters). This concrete is used for sidewalks and runways.

What Makes Up Cement?

Cement is made by getting crushed limestone mixed with sand mixed in with ground clay, shale, iron ore, fly ash, and alternative raw materials. Depending on the company's procedure on making cement the amounts of these materials recipe can vary.

How do minerals form?

It forms when water moves through cracks if the earth’s crust. As it moves in-between rocks and other minerals it interacts with other rocks materials creating a fluid. This fluid then cools to form different types of minerals we know today.

How is Coares Aggregate Collected?

Coarse aggregate and most minerals are collected from blasting quarries. Once collected they are shipped to a refinery via trucks. Once at a refinery the rocks are grounded up to the desired size of the consumer. Then are shipped to factories like Lafarge and other incorporations that make concrete.

What's the most common type of coarse aggregate?

Natural river gravels and crushed rocks like granite and limestone are commonly used for structural concrete. The reason why it is used so much is because it improves the strength and lowers the possibility of an alkali-silica reaction. It is also a lot cheaper compared to other aggregates.

What is coarse aggregate?

Coarse aggregate is one of the many materials that makes up concrete, coarse aggregate is made up of a wide variety of materials. It is made up of rock quarried from ground deposits. The ground deposits include river gravel and crushed stone.

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What is an alkali-silica reaction?

An alkali-silica reaction is a chemical reaction between siliceous minerals in the aggregate and the alkalinity of the concrete. This produces an expansive gel that causes the concrete to crack and buckle.

What is buckling?

Buckling is a form of failure under a mass amount of compression causing the structure to crack and fall apart. This is one of the most common ways that concrete will fall apart.

What makes up water?

Water is made up of two hydrogen atoms and one oxygen atom. These atoms make up a water molecule. When there are large amounts of these molecules it can create large bodies of water like oceans or rivers. Construction workers then collect the water to make cement or concrete.

What is an alkali-silica reaction?

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What makes concrete solidify?

Water helps the concrete solidify through a process called hydration. When hydration occurs the water and calcium silicates in the cement found in concrete react to cause the materials to bond over a period of time.

What is hydration?

Hydration is a chemical reaction when the water molecules interact with the calcium silicates causing it to bond over time.
Thus causing the concrete to harden. This process does take a long amount of time taking up to even days for certain types of concrete.

What happens to concrete when you increase the size of coarse aggregate.?

When increasing the size of the coarse aggregate heat is a lot harder to enter the concrete. Mainly because it takes longer for larger objects to absorb energy. But the larger sizes of coarse aggregate can retain more heat.

<u>Concrete Recipes</u>

Recipe Option 1

- 1 Part Portland Cement.
- 1 1/2 Part Gravel.
- 1 Part Sand.
- 1/2 Part Water

Recipe Option 2

- Air (6%)
- Cement (11%)
- Coarse aggregate (41%)
- Water (16%)
- Fine aggregate (26%)

What's a way to reduce the heat island effect? What can you do?

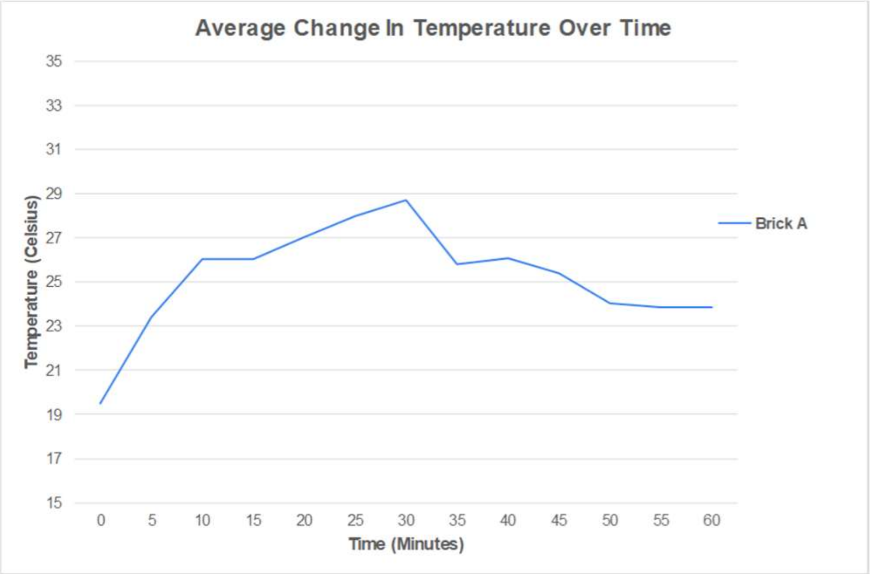
To help with this growing problem there are a lot of things you can do. The first way you could help is letting people be aware of heat islands. Because if you have more people putting their minds to this issue you could help reduce the impact of the heat island effect. That means we will have more people tackling this issue. Another way you could help is to plant more green spaces and just plant any plants. This will help because plants lose water to the atmosphere causing these areas to cool. One last way that you could help tackle this issue is to do projects like the one that I'm doing.

Observations and Charts

Brick A

	Temperature (Celcius)									
Time (Minutes	A1	A2	A3	A4	A5	A6	A7	A8	A9	Average
0	18.00	18.20	19.60	18.90	18.90	20.40	20.40	19.70	21.20	19.48
5	23.20	25.30	22.50	22.50	23.20	22.90	23.20	23.90	23.90	23.40
10	24.50	27.50	27.20	23.80	25.90	27.20	23.10	27.20	27.90	26.03
15	25.70	27.90	25.20	23.80	25.90	27.30	25.20	25.90	27.20	26.01
20	27.20	29.30	29.40	27.20	27.30	25.90	25.90	26.50	24.50	27.02
25	27.50	30.60	30.20	27.20	29.30	26.60	25.90	27.90	26.60	27.98
30	28.00	32.50	32.50	28.00	31.30	26.60	25.30	28.00	26.00	28.69
35	25.40	27.50	26.70	25.20	26.20	26.10	24.80	25.50	24.80	25.80
40	25.20	25.70	25.00	25.00	25.10	24.30	24.40	25.70	34.40	26.09
45	23.80	25.20	24.50	24.50	24.50	23.00	24.30	26.50	32.20	25.39
50	22.60	24.30	23.90	23.90	24.60	23.90	24.00	24.60	24.30	24.01
55	23.20	23.70	24.00	24.00	24.50	23.30	24.00	24.00	24.00	23.86
60	24.10	24.10	23.40	24.10	24.80	24.10	22.70	24.10	23.20	23.84

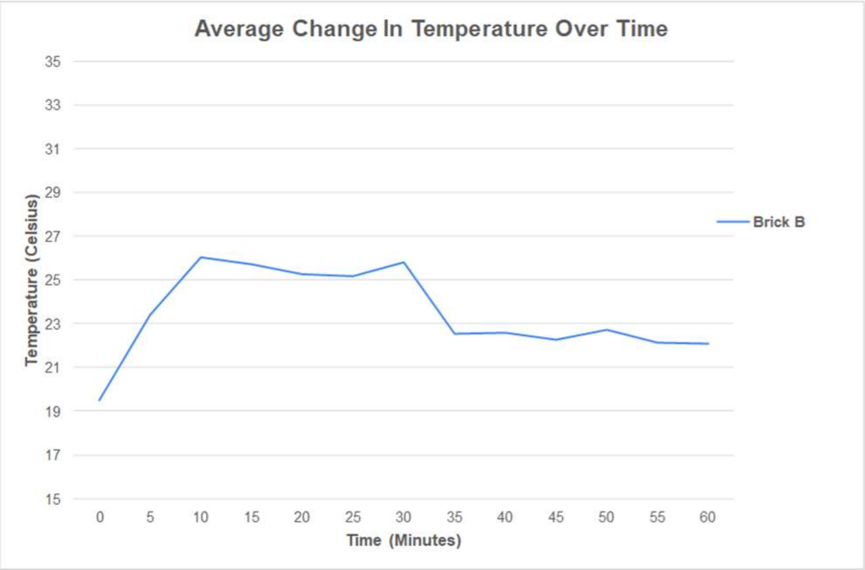
Heating: 0.307 Degrees per minute
Cooling: 0.161 Degrees per minute



Brick B

Time (Minutes	A1	A2	A3	A4	A5	A6	A7	A8	A9	Average
	Temperature (Celcius)									
0	18.0	18.2	19.6	18.9	18.9	20.4	20.4	19.7	21.2	19.48
5	23.2	25.3	22.5	22.5	23.2	22.9	23.2	23.9	23.9	23.40
10	24.5	27.5	27.2	23.8	25.9	27.2	23.1	27.2	27.9	26.03
15	25.7	27.9	25.2	25.8	27.2	25.7	21.7	25.9	26.3	25.71
20	21.3	26.9	23.2	21.8	29.4	28.9	21.7	26.6	27.4	25.24
25	21.2	28.1	22.7	21.9	30.1	23.3	21.9	27.5	29.7	25.16
30	22.0	28.1	22.7	22.9	31.1	24.3	21.9	28.1	31.0	25.79
35	20.8	24.3	21.8	20.1	24.3	21.5	22.2	25.0	22.9	22.54
40	19.4	23.7	20.9	20.8	24.4	22.5	22.9	25.0	23.7	22.59
45	20.2	23.1	21.6	20.9	23.1	21.6	22.4	24.3	23.1	22.26
50	22.5	22.5	21.1	21.1	23.9	22.5	21.8	25.6	23.4	22.71
55	20.4	22.6	21.4	20.4	23.3	21.1	21.9	24.0	24.0	22.12
60	19.8	23.3	20.5	20.5	23.4	22.0	22.0	24.5	22.6	22.07

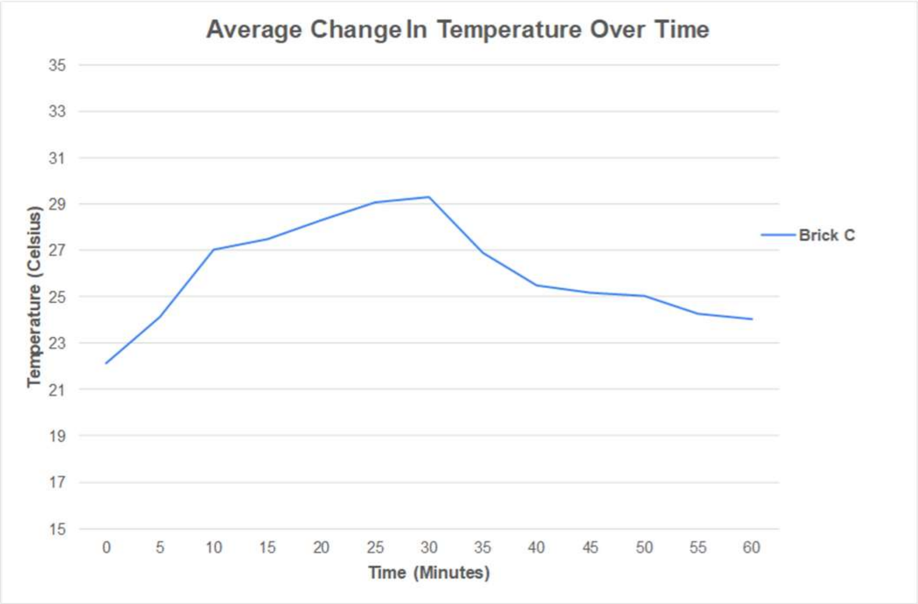
Heating: 0.210 Degrees per minute
Cooling: 0.124 Degrees per minute



Brick C

Time (Minutes	A1	A2	A3	A4	A5	A6	A7	A8	A9	Average
	Temperature (Celcius)									
0	20.7	22.8	22.1	20.7	21.4	21.7	22.8	23.5	23.5	22.13
5	22.2	25.0	24.3	22.2	24.3	23.6	24.3	25.0	26.3	24.13
10	23.7	27.1	29.2	25.1	28.5	29.1	25.8	29.1	25.7	27.03
15	23.8	27.9	28.6	25.4	29.9	28.6	25.2	29.9	27.9	27.47
20	23.9	30.0	28.6	25.3	30.6	31.9	24.6	31.3	28.6	28.31
25	26.4	31.6	31.7	25.4	30.7	29.3	26.7	30.6	29.4	29.09
30	25.4	29.3	30.1	26.7	32.9	30.1	26.2	32.0	31.0	29.30
35	24.6	26.6	27.3	25.4	28.4	28.0	26.0	28.6	27.3	26.91
40	23.7	25.8	26.5	24.0	25.8	26.5	25.1	27.1	25.0	25.50
45	23.4	26.2	25.5	24.8	25.5	25.4	24.6	26.2	25.0	25.18
50	23.3	24.6	29.3	24.6	23.2	24.6	23.9	25.9	26.0	25.04
55	23.7	24.4	25.1	23.7	25.1	24.4	23.7	23.3	25.1	24.28
60	23.9	23.6	24.8	23.6	24.2	24.3	22.9	23.9	24.9	24.01

Heating: 0.24 Degrees per minute
Cooling: 0.176 Degrees per minute

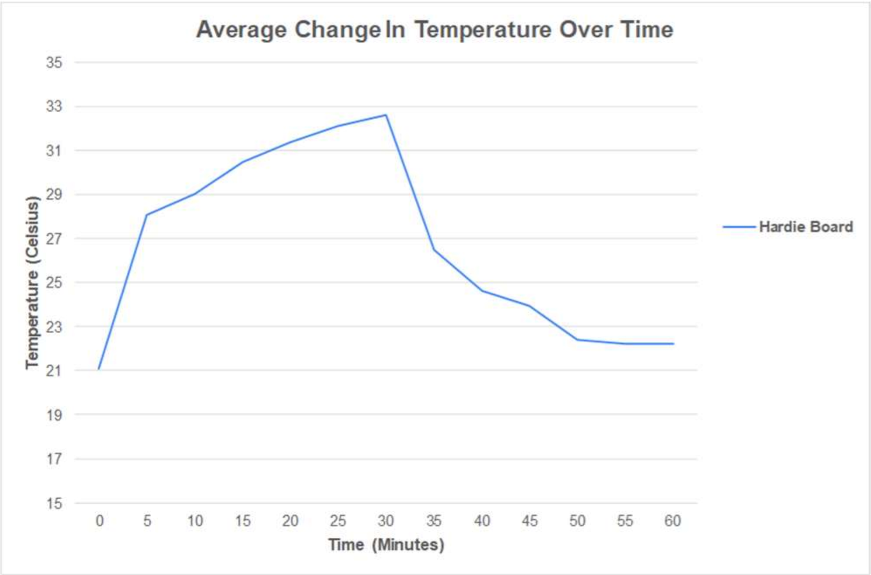


Hardie Board

Time (Minutes	Temperature (Celcius) A1	A2	A3	A4	A5	A6	A7	A8	A9	Average
0	20.6	21.3	20.6	21.3	21.3	20.6	20.7	22.1	21.3	21.09
5	24.3	32.5	25.6	27.6	36.0	25.5	31.1	23.9	26.2	28.08
10	25.7	33.2	25.7	27.1	42.1	25.3	30.0	23.9	28.0	29.00
15	25.1	37.2	27.8	26.5	43.4	30.5	25.8	30.5	27.5	30.48
20	25.2	36.8	25.9	28.2	49.5	29.3	25.2	35.9	26.6	31.40
25	26.6	36.6	28.0	27.3	50.4	28.0	40.0	26.0	26.0	32.10
30	26.7	36.3	28.2	28.4	50.4	32.2	25.7	38.1	27.4	32.60
35	23.1	28.6	25.2	24.5	34.2	23.2	25.6	29.3	24.5	26.47
40	23.4	25.2	24.7	23.8	29.2	23.2	23.8	25.8	22.4	24.61
45	21.7	23.8	24.5	22.4	28.7	21.6	23.8	25.9	23.1	23.94
50	21.2	23.1	20.2	23.1	24.5	21.0	22.4	24.5	21.7	22.41
55	21.0	23.2	21.1	22.5	23.1	20.0	22.1	23.1	23.8	22.21
60	21.0	23.2	21.1	22.5	20.0	23.1	22.1	23.1	23.8	22.21

Heating: 0.388 Degrees per minute

Cooling: 0.346 Degrees per minute

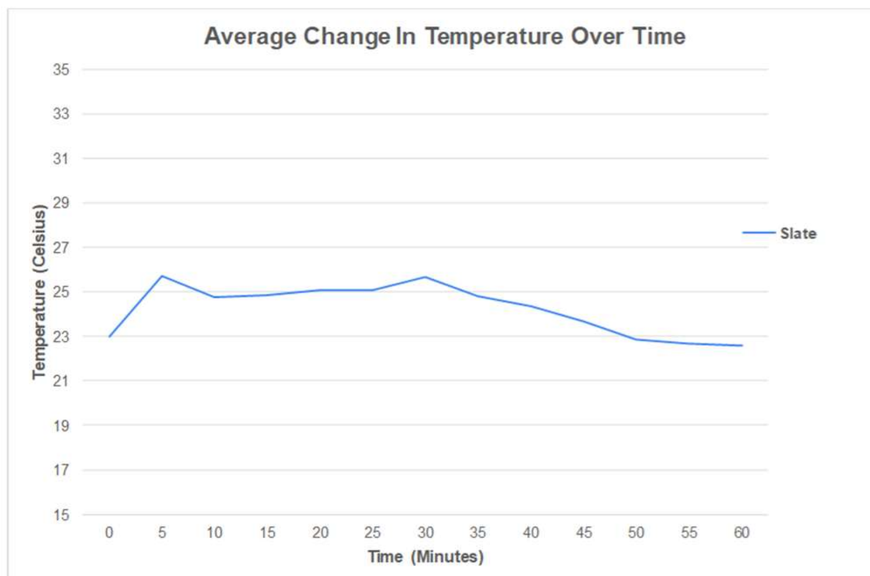


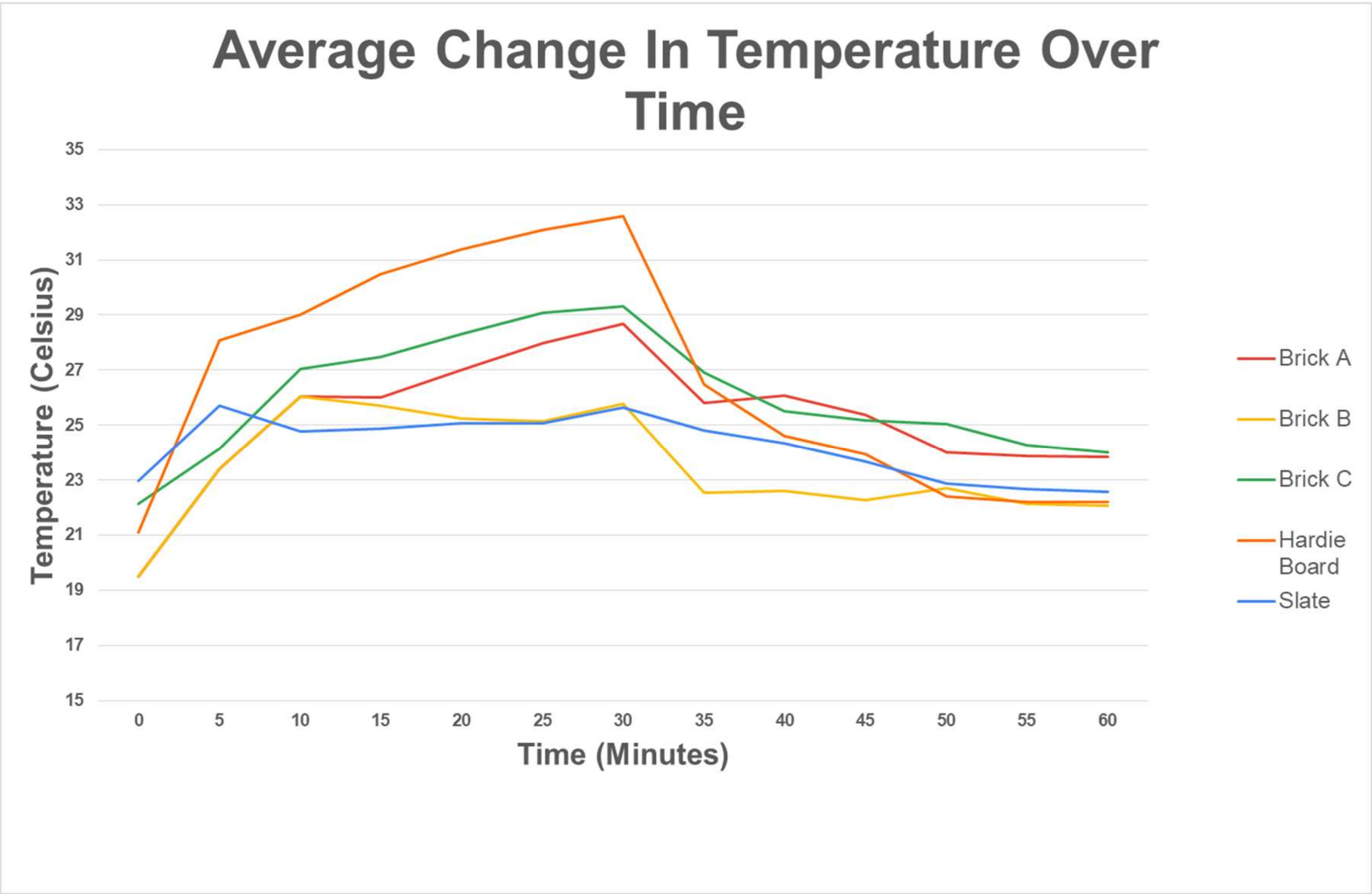
Slate

Time (Minutes	Temperature (Celcius)									
	A1	A2	A3	A4	A5	A6	A7	A8	A9	Average
0	23.2	22.9	21.9	24.6	23.7	22.6	22.3	22.6	23.0	22.98
5	22.6	23.9	25.4	23.2	25.3	36.0	23.2	26.6	25.3	25.72
10	22.3	24.4	25.1	23.3	25.8	26.0	23.0	27.6	25.4	24.77
15	22.8	23.5	25.6	23.5	24.9	26.9	23.5	26.9	26.2	24.87
20	22.5	24.5	26.0	23.2	26.6	28.0	23.2	25.3	26.3	25.07
25	22.3	24.3	25.3	23.0	25.8	28.0	23.0	25.8	28.2	25.08
30	22.8	24.9	27.0	22.8	26.2	29.0	22.8	27.0	28.3	25.65
35	22.7	24.0	26.1	23.4	25.4	26.8	23.4	25.4	26.1	24.81
40	23.3	24.7	25.6	22.6	25.4	25.4	22.6	24.7	24.7	24.33
45	22.6	23.3	24.7	23.3	23.3	24.7	22.6	24.0	24.6	23.68
50	21.4	22.8	23.5	22.1	23.2	23.5	22.1	24.0	23.2	22.87
55	21.8	22.0	22.7	22.0	23.5	22.8	22.7	23.4	23.1	22.67
60	20.5	21.9	23.2	22.7	22.7	22.7	22.6	23.4	23.4	22.57

Heating: 0.089 Degrees per minute

Cooling: 0.102 Degrees per minute





Average Change In Temperature Over Time
Temperature (Celsius)
35
33
31
29
27
25
23
21
19
17
15
0
5
10
15
20
25
30
35
40
45
50
55
60
Time (Minutes)
Brick A
Brick B
Brick C
Hardie Board
Slate

Observations:

Brick (A):

Qualitative:

With a similar shape to Brick C this piece of concrete was a very interesting sample to test with its hot center shown in the thermal imaging camera. This rectangular brick had a large size coarse aggregate inside of it. There was also a lot of small holes inside of the concrete making this pores concrete be able to have fluids pass though the concrete. While testing I noticed that in the inferred photos you could see the area that the lamp was directed to and with it came a large red circle. Would the heat source (Sun) Have a similar outline of its surface area on the concrete? What would it look like?

Quantitative:

This brick was a very interesting brick to test when observing the data. One thing I noticed was that the brick did not have a general rate of heating and cooling and on the graph it showed that the heat would spike and then level out. But did heat up at around 1-2 degrees Celsius per 5 minutes. The concrete did cool at a gradual rate and did even out like how it heated up.

Brick (B):

Qualitative:

Like the other two brick samples that I tested this brick was about 1-2 inches thick. This sample also shared that it is pours. This brick also is a similar color to both bricks. But a major difference between this brick and the others is that this brick is about the same size as the Hardie board and about the same amount of thickness as it.

Quantitative:

During this experiment there was a lot to notice about the numbers coming in. First of all similar to the other bricks this sample heated up very slowly but gradually and cooled slowly and gradually. And this sample only reached about 26-27 degrees Celsius at its peak. But it did retain its heat over the cooling time for about 15 minutes straight.

Brick (C):

Qualitative:

During this experiment there was a lot to notice about this building material. This brick had lots of small little holes along the surface of the brick. This causes the brick to be pores and be able to have fluids pass thought the material. This brick also had very rigged sides do then it could be interlocked with other bricks. In the beginning of the experiment the inferred camera showed that the brick was blue and almost purple compared to its surroundings. Which was very different compared to the other samples. Also before the experiment I washed all the samples and this brick had a lot of dirt that came off of it. I believe this was because of the pours.

Quantitative:

During the experiment this concrete slab heated up very slowly up to the point where it only reached 30 degrees Celsius. While all the other slabs reached up to 50 degrees Celsius. But even though it did not reach a very high temperature it did retain all the heat for about 15 minutes. But overall a very interesting sample to test.

Hardie Board:

Qualitative:

This concrete sample was very unique compared to the other samples that I tested. First of all this concrete sample had a very smooth texture unlike the bricks or natural concretes. This smooth surface probably helped the concrete reflect heat from the heat lamp. Second the concrete also had a wood like texture meant to have a wood aesthetic for buildings. Another thing about this concrete is that the concrete was somewhat thin with a thickness of about 2-3 cm wide. Another thing I noticed was that you could see the area of the lamp in the inferred camera.

Quantitative:

During this experiment the heat absorption of the concrete was very different compared to the other samples. One thing that really stood out from the other samples was that this sample absorbed the heat very rapidly. I even noticed that the laser thermometer was reading 1-2 degrees Celsius hotter than the temperature ready 5 minutes prior. Because of this at its peak it almost reached 50 degrees Celsius. But after gaining all this heat the energy had to go somewhere. So after the 30 minutes of heating the concrete I turned off the light only to find that the concrete had lost 20 degrees Celsius in only 5 minutes.

Slate:

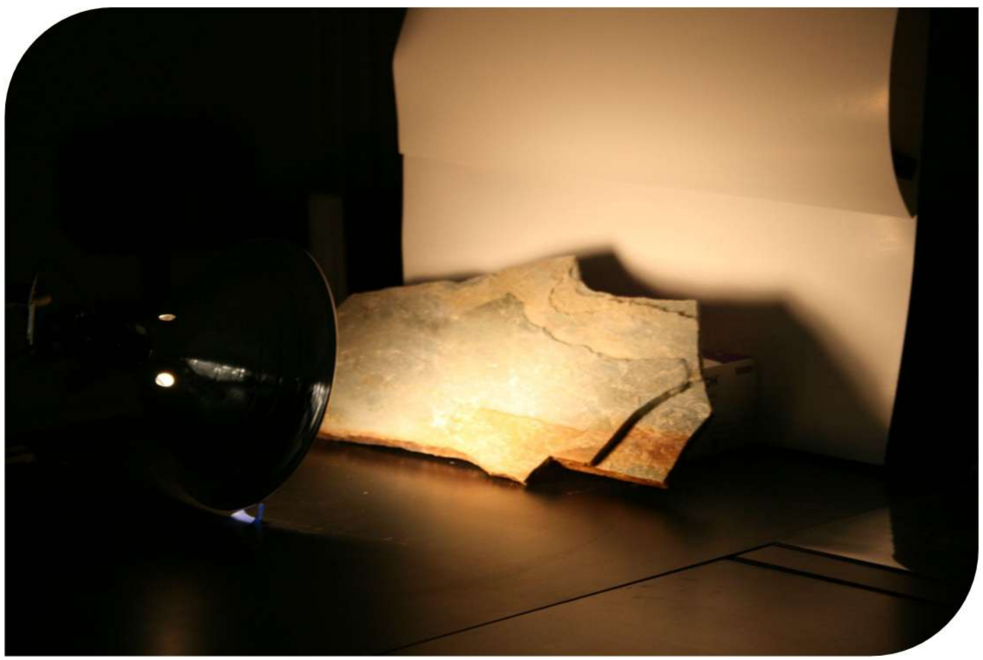
Qualitative:

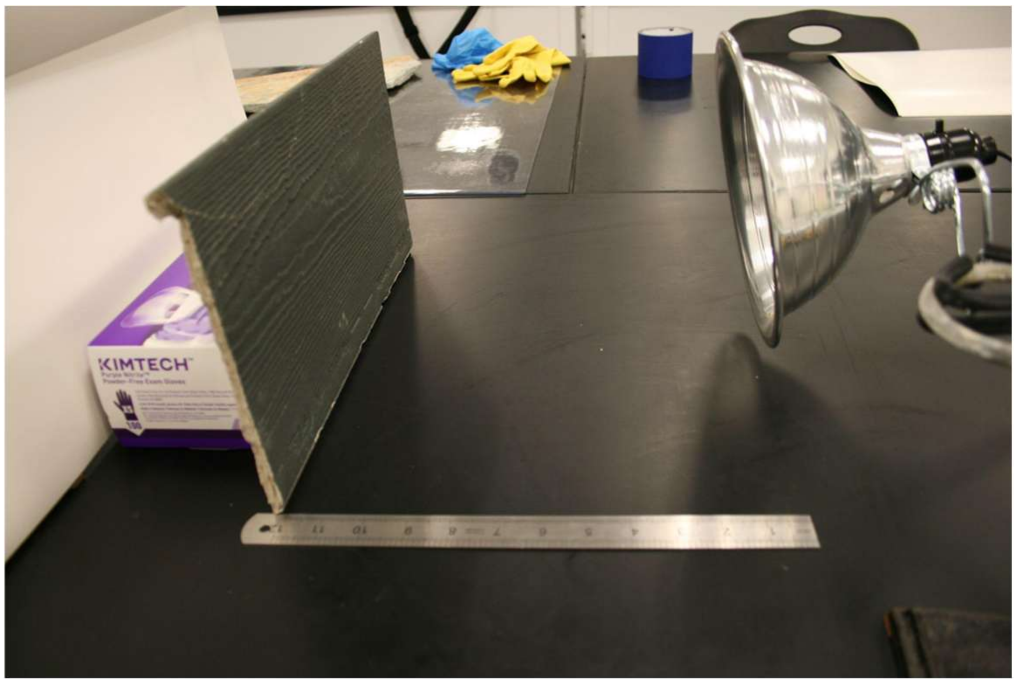
This concrete sample had a verity of colours and lots of unique details. First of all this sample is an irregular shape meaning none of the sides are the same. So when making my 3x3 array this one was a little challenging. Also on the concrete there was a wide variety of colors from beige to oranges to even some red. There were a lot of colors everywhere. It almost looked as if it came straight out of a mountain. It also had an interesting shape that almost seemed as if it were unnatural and deformed.

Quantitative:

During the experiment this concrete was very similar to the other bricks. One way that makes it similar is that the concrete gradually heated and gradually cooled. Another thing that makes it similar to brick B is that it would heat up and then level out.

Photos While Testing

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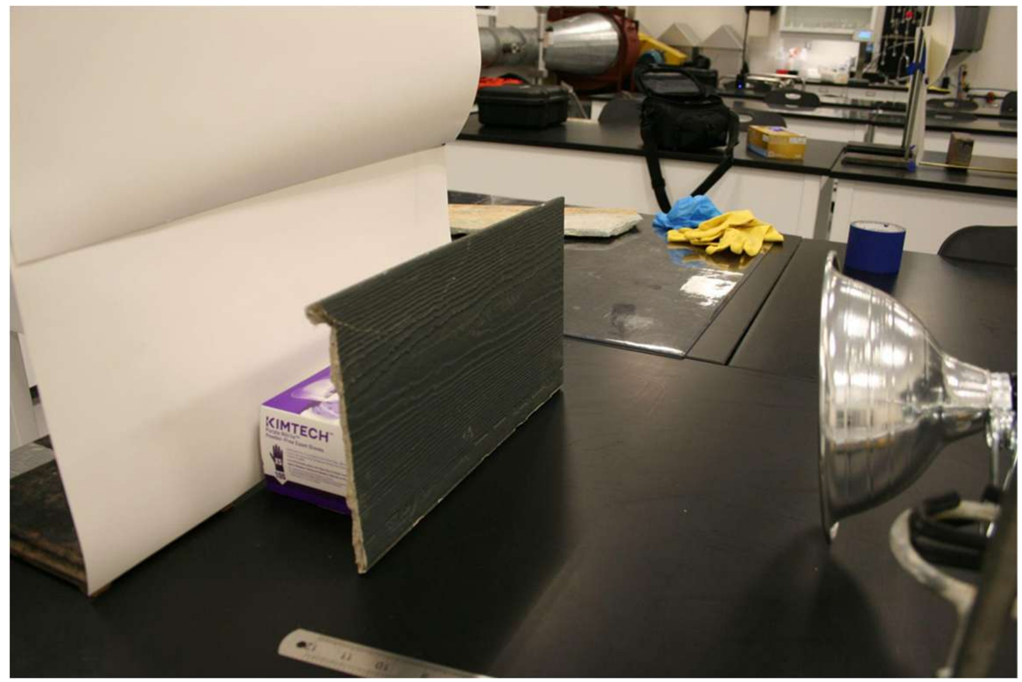
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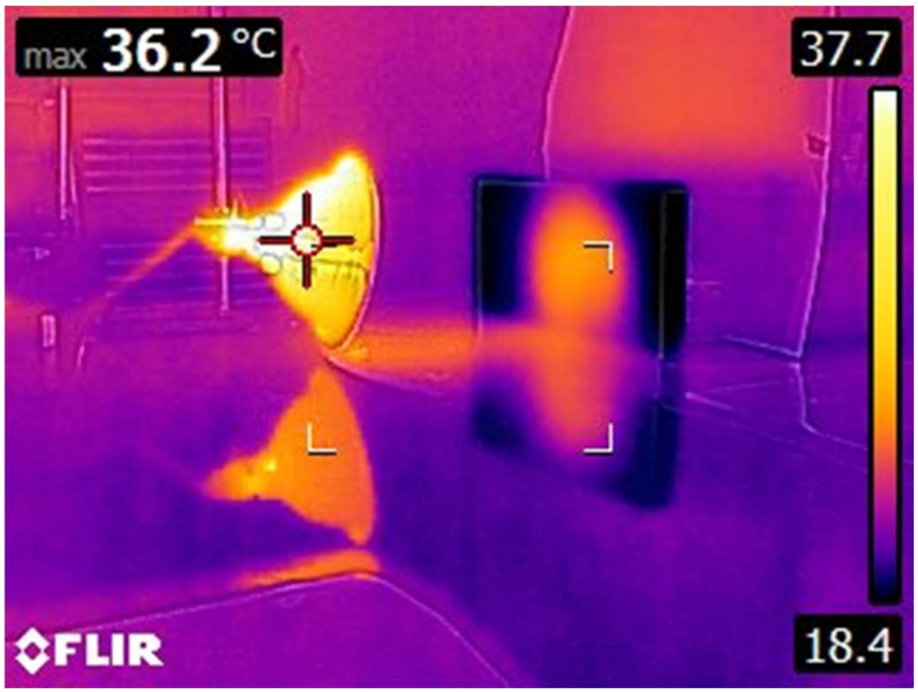
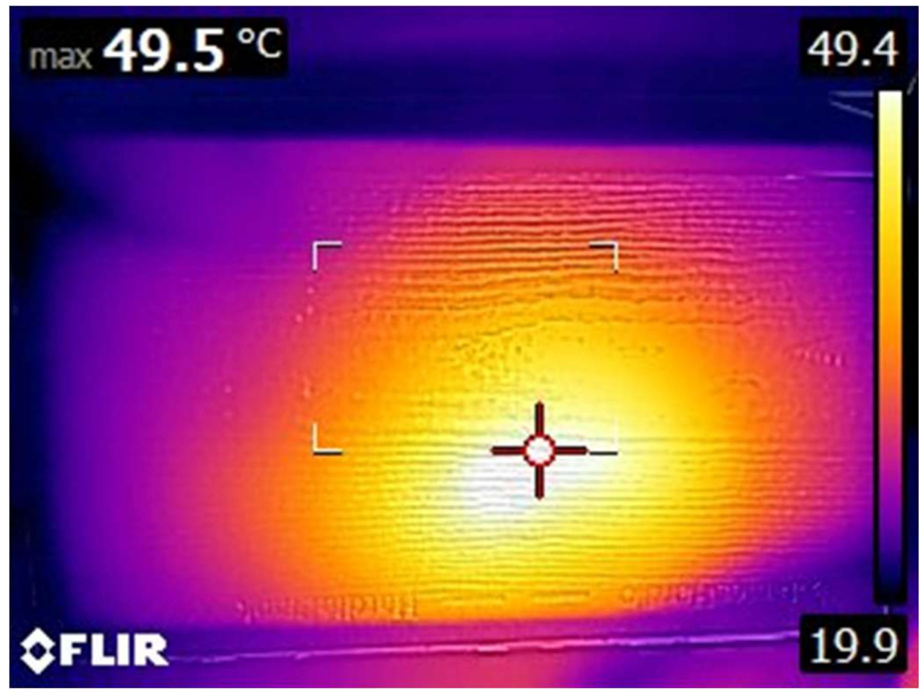
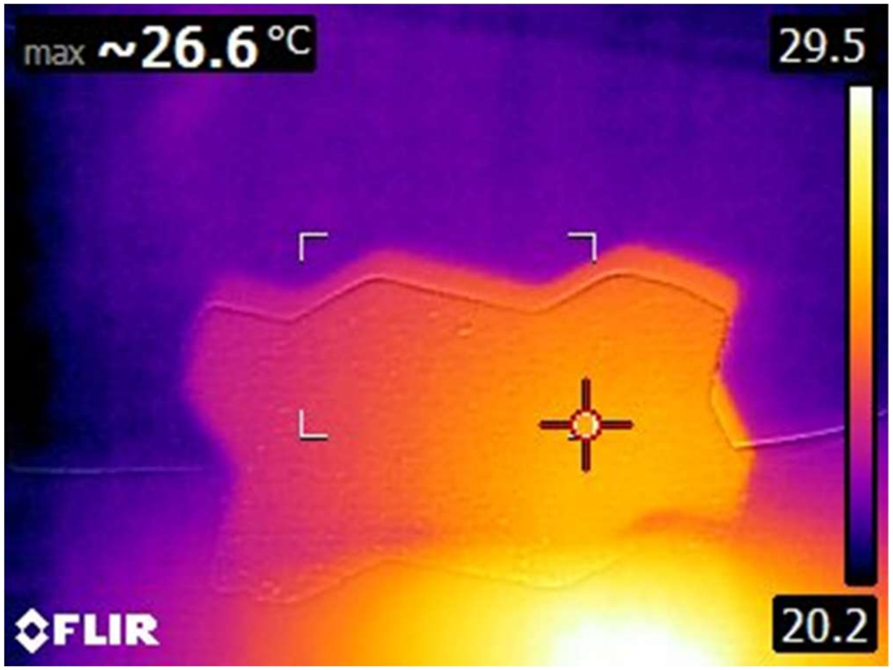
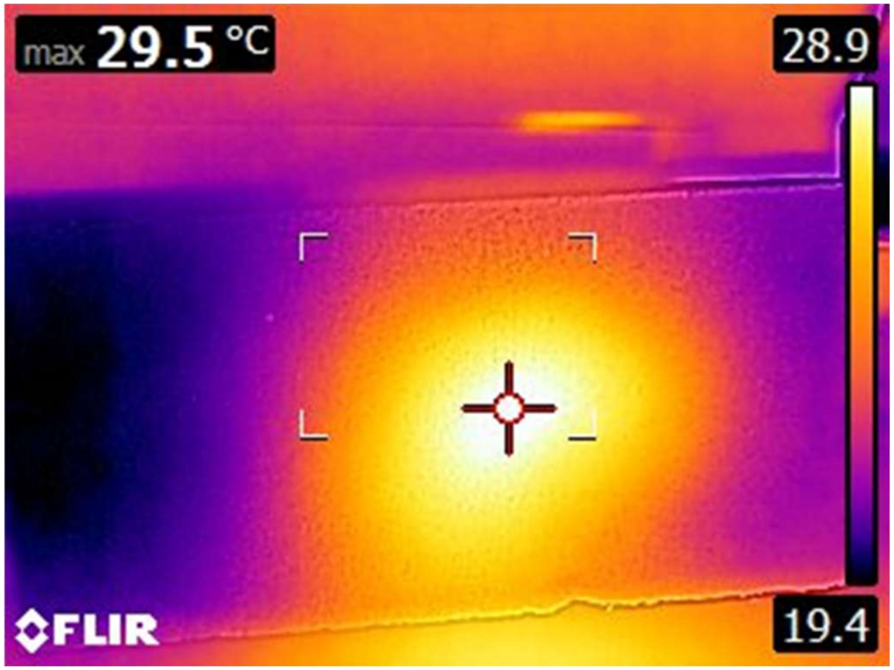

max 36.2 °C
37.7
18.4
FLIR


max 49.5 °C
49.4
19.9
FLIR


max ~26.6 °C
29.5
20.2
FLIR


max 29.5 °C
28.9
19.4
FLIR

Concrete Characteristics:Brick (A)

Colour	Darkish red
Aggregate Size	20-30mm
Texture/Finish	A rough edged and rocky finish with a texture of sandpaper.
Shape	(Rectangular prism)

Brick (B)

Colour	Very dark red
Aggregate Size	25-35mm.
Texture/Finish	Like Brick (B) but a lot more sharper edges with a more roughed out texture. Also rocky.
Shape	(Rectangular prism/Irregular Shape)

Brick (C)

Colour	Dark red
Aggregate Size	20-35mm
Texture/Finish	A rough texture with somewhat rounded corners. This sample also was very rocky like the two other bricks.
Shape	(Rectangular Prism)

Hardie Board

Colour	This concrete had a dark grey finish. But the main component of the concrete was a light grey.
Aggregate Size	10-15mm
Texture/Finish	This slab of concrete had a very smooth and laminated texture with small grooves that resemble a wooden texture.
Shape	(Rectangular Prism)

Slate

Colour	A mixture of colors with some Reds, Browns, All sorts of greys and even a little bit of black.
Aggregate Size	15mm
Texture/Finish	This concrete slab had a variety of textures including rough and even some parts being somewhat smooth. It also had multiple Jagged vertices.
Shape	(Irregular Shape)

Analysis:

There was a lot that I learned from this experiment. And the results were very clear. Underneath I put the samples in order from the smallest impactor to heat islands to the biggest impactor to the heat island effect.

Brick (B)	
Heating:	0.210 Degrees per minute
Cooling:	0.124 Degrees per minute
Slate	
Heating:	0.089 Degrees per minute
Cooling:	0.102 Degrees per minute
Brick (A)	
Heating:	0.307 Degrees per minute
Cooling:	0.161 Degrees per minute
Brick (C)	
Heating:	0.24 Degrees per minute
Cooling:	0.176 Degrees per minute
Hardie Board	
Heating:	0.388 Degrees per minute
Cooling:	0.346 Degrees per minute

1. Brick (B):

After a lot of testing Brick (B) came out to be the best sample to help fight the heat island effect. One reason why I believe this concrete did so well at not absorbing so much heat is because the aggregate size was so high that there was lots of space in between the rocks/aggregates and because of this the energy could not transfer throughout the brick and when it came time to cool there was not enough energy to keep the brick so hot.

2. Slate:

There are so many reasons why the slate is such a great concrete to help fight ageist the heat island effect. First of all the Slate has a large size of coarse aggregate inside of it. Because of this large size of coarse aggregate there are less rocks(Aggregates) so close to one another and there are a lot less coarse aggregate rocks inside of the concrete. Since they are so spread apart though the concrete the thermal storage comp asity is lower than the other concretes. Making this concrete such a great concrete to help fight the heat island effect.

3. Brick (A):

There are so many reasons why Brick (B) is the 3rd best option for fighting the heat island effect. First of all brick B had a somewhat small size coarse aggregate inside of it meaning that it has a medium size aggregate like 9.5 mm or slightly larger size. The reason why it's the 3rd best id because you can't fit that many rocks/aggregates inside of the concrete because of its aggregates size. Because of this the thermal storage in the brick is smaller than Brick (D).

4. Brick (C):

The next sample with the second highest impactor to the heat island effect is Brick (D). There are so many reasons why I think that this brick should be the second highest impactor to the heat island effect. First of all this sample had a somewhat small size aggregate As I explained with the Hardie board since the size is so small the concrete can hold more of them making the concrete be able to hold a lot more heat because more coarse aggregate can fit inside of the brick. And the surface area of the smaller sizes of aggregates are a lot larger.

5. Hardie Board:

Hardie board was the sample with the sample that had the highest rate of heat absorption out of all the other samples. There are so many reasons why this sample had the highest increase of temperature with this sample. Because darker colors absorb more heat and since this concrete sample has a dark gray laminate overtop the concrete it allows the concrete to absorb more heat. Another reason is that since the coarse aggregate size is so small it allows more of the partials to be inside of the concrete. And with smaller particles the concrete can heat up a lot faster than concrete samples with a larger size. Just like how if you take a small quantity of water it will boil faster than larger quantities of water. Because of this it allows the thermal storage of the concrete is increased. But because they're so small they can't retain the heat so the heat inside of the concrete is lost. As shown in my graph.

Conclusion:

In conclusion my hypothesis was incorrect. My hypothesis was:

“If I heat multiple concrete samples that have different sizes of coarse aggregate then the sample with the largest sized aggregate will absorb the most heat because larger sized objects can store more energy.”

Instead, the results showed that the sample with the largest sized aggregate (Brick (B)) absorbed the least heat and the sample with the smallest sized aggregate (Hardie Board) absorbed the most heat. This is because the smaller sized coarse aggregate has greater surface area and more particles that can heat up faster because of its size.

Sources of Error:

During an experiment not everything can go to plan. And during my experiment a lot of things went wrong.

1st of all the angle of the heat lamp could have varied throughout the experiment.

- This could cause the concrete to cool in areas that were not supposed to. Causing the concrete to cool or lose the heat.

2nd of all the light turned on for about 5 seconds after I accidentally triggered the movement sensor.

- Could have caused the concrete to absorb the radiated heat from the light bulbs. But this was only for a short period of time so it probably did not affect the results very much.

Another source of error is while testing the first (Hardie board). The concrete fell over.

- When the concrete fell over it could have lost a lot of heat to the lab bench. Or the table could have been hotter than the concrete.

Sources of Error: (Continued)

Also during the experiment the lights from Dr.O'Sullivan's lab could have radiated heat.

- This could cause any of the slabs of concrete to heat up more than the others. This would affect my data collection a lot.

Some of the concrete samples were not the same size.

- This could have caused some areas of the concrete could get hotter than the other side of the concrete.
- Also the lamp could have more of the concrete sample covered by the lamp.
- The samples were also not the same amount of thickness and this could have caused the thinner samples to absorb heat faster than the thicker samples.

I did my best to find concrete that did not have as many variables in the concrete. But some of the concrete samples were different from each other.

- This could change the results and how we view different sized aggregates.

Real World Applications:

With this newly found information there are so many real world applications. And as well as new innovative ways that we could use to tackle the heat island effect.

Tackling the heat island effect

First of all you could use this information to help with solving the heat island effect. To help with this issue if you have a choice between using a small size aggregate or a larger size you should use the larger size aggregate because larger sizes get to a higher temperature a lot slower compared to smaller size aggregates. With this information you could plan out all sorts of ways to fight the heat island effect. Another thing to consider about larger size aggregates is that the concrete is overall a lot more strong compared to smaller size aggregates. So overall if you can use larger size aggregates in concrete.

Another thing that the city of Calgary could do to help fight the heat island effect is to incorporate more large size aggregate into their city plans. This would make the city overall cooler because of the low rate of heating up. And maybe some developing companies could use this information to help with this issue. Because of this they could make their company look like they care about the environment. And large size aggregate is very cheap because it’s not been ground down as much as other smaller sized aggregates. Also less processing of the material. Meaning we don’t need to build any refinery in Canada to process the materials.

Thermal Storage

Knowing that concrete absorbs heat there is a possibility that we could trap heat and use it for other purposes. An example of this is capturing energy from the sun and then using this energy/heat we could trap heat inside of your house or even in any other building. This could ultimately lower prices of heating homes and other buildings. Thus reducing the impact to climate change because of the lack of fossil fuels being burned. Because of the less impact to climate change we would see a lot less natural disasters and a lot less animal casualties

Other Uses

Aside from using concrete for thermal storage or tackling the heat island effect. There are all sorts of ways that you can use this information on the heat absorption of concrete.

One of these uses is possibly cooking or baking using concrete. One way of doing this is to make an oven using a small size of coarse aggregate and then bake your desired item inside of the oven. You could possibly even do this on a hot day so you could use the energy of the sun.

Another thing you could do to cook is to make a small concrete slab with a small size of coarse aggregate and cook something like an egg or any other item that you are cooking. Using these two techniques of cooking with concrete could help save energy and help with lowering the impact of climate change.

Examples of ways you could use this information. And where we could use certain concrete types.

There are lots of ways you could apply this information to the real world. And lots of ways that you could apply this information to different concrete structures.

Side walks/Road

With the information that I found from my science fair project there is A lot I would suggest for building sidewalks.

First of all a larger size aggregate would be preferable because of its strength and ability to withstand lots of forces. A larger size of coarse aggregate would also be helpful because it absorbs the least amount of heat from a heat source compared to a smaller size of coarse aggregate. So overall using a large size of coarse aggregate would be preferable.

Another thing to consider is that sidewalks are heavily used on a day to day basis. So it will need the strength to withstand all the walkers and bikers and even runners. Because of this I believe and my project reflects this is that a large size of coarse aggregate would be the most optimal size of coarse aggregate for sidewalks.

Rooftops/Any Outer Part of the Building

Rooftops or any surface very exposed to the sun are big impactors to the heat island effect. And could heat up cities and urban areas greatly. So while choosing a concrete type with the right aggregate is very important. From the results I found from my experiment is that larger size aggregates are great for keeping the heat out of the building. So I would suggest building your rooftops with a larger size aggregate to lower the impact to the heat island effect. The only thing about building a roof with a heavy bulker concrete is that you will need the supports to hold up.

Also you do need to consider where you roof is and in what part of the world. For example a large size of coarse aggregate in a hot area like in Africa having a large size of coarse aggregate would be helpful because it could help reduce the temperature in your home. But in the artic having a small size aggregate would be helpful because of its ability to absorb heat.

One thing that you could also do in the future is to change the concrete on roof tops throughout the year. For example in Calgary we have very hot summers and very cold winters. We could have small size aggregate in the winter and large in the summer.

Structural Parts of a building

For these structures you cannot manipulate the size of aggregate. The reason why that there is standards so then the building would not collapse. The standard is between 9.5mm and 37.5mm. And even I would suggest this from the information that I found while doing my experiment.

First of all 9.5 to 37.5 are very large sizes of coarse aggregate. These sizes are great for holding up a building because of its ability to withstand too much force. Larger sizes are great for all sorts of forces like compressive forces and tensile forces and they also tend not to break.

Bibliography:

BOOKS

A century well built: 100 Years of Engineering and Geoscience in Alberta. (2021). Association of Professional Engineers and Geoscientists of Alberta.

Concrete: From the Ground Up. (2022). Candlewick Press.

"Cement and Concrete." *The World Book Encyclopedia,* Volume 3, Field Enterprises Educational Corporation, 1969, pp.254-256.

Websites Accessed

What Is an Urban Heat Island? (n.d.). NASA Climate Kids. Retrieved November 25, 2024, from https://climatekids.nasa.gov/heat-islands/

Heat Island Effect | US EPA. (n.d.). Environmental Protection Agency (EPA). Retrieved November 25, 2024, from https://www.epa.gov/heatislands

Druckenmiller, H. (2023, March 14). *Urban Heat Islands 101*. Resources for the Future. https://www.rff.org/publications/explainers/urban-heat-islands-101/

EasyMix Concrete UK Ltd. (2019, March 6). EasyMix Concrete UK Ltd. https://www.easymixconcrete.com/news/types-of-concrete-and-their-strengths/

Heat island. (n.d.). Encyclopedia Britannica. https://www.britannica.com/science/heat-island

NASA's ECOSTRESS Detects "Heat Islands" in Extreme Indian Heat Wave - NASA. (2022, May 12). https://www.nasa.gov/missions/ecostress/nasas-ecostress-detects-heat-islands-in-extreme-indian-heat-wave/

Stewart, I. D., Krayenhoff, E. S., Voogt, J. A., Lachapelle, J. A., Allen, M. A., & Broadbent, A. M. (2021). Time Evolution of the Surface Urban Heat Island. *Earth's Future*, *9*(10). https://doi.org/10.1029/2021ef002178

Heat island. (n.d.). Encyclopedia Britannica. https://www.britannica.com/science/heat-island

NASA's ECOSTRESS Detects "Heat Islands" in Extreme Indian Heat Wave - NASA. (2022, May 12). https://www.nasa.gov/missions/ecostress/nasas-ecostress-detects-heat-islands-in-extreme-indian-heat-wave/

Stewart, I. D., Krayenhoff, E. S., Voogt, J. A., Lachapelle, J. A., Allen, M. A., & Broadbent, A. M. (2021). Time Evolution of the Surface Urban Heat Island. *Earth's Future*, *9*(10). https://doi.org/10.1029/2021ef002178

Zafra, M. (2023, July 31). The floor is lava. *Reuters*. https://www.reuters.com/graphics/CLIMATE-CHANGE/URBAN-HEAT/zgpormdkevd/

EPA. (2014, June 17). *Heat Island Impacts*. US EPA. https://www.epa.gov/heatislands/heat-island-impacts
Tradienearme. (2024). Tradienearme.com.au. https://tradienearme.com.au/types-of-concrete-finish/

Brian Stone Jr. (2024, August 19). *Ancient Rome had ways to counter the urban heat island effect – how history's lessons apply to cities today*. The Conversation. https://theconversation.com/ancient-rome-had-ways-to-counter-the-urban-heat-island-effect-how-historys-lessons-apply-to-cities-today-234546

Neave Interactive. (2024). *Temperature Forecast Map | Zoom Earth*. Zoom Earth. https://zoom.earth/maps/temperature/#view=51.074988

Britannica. (2019). Temperature. In *Encyclopædia Britannica*. https://www.britannica.com/science/temperature

Cool Walls | HEATISLAND. (n.d.). Heatisland.lbl.gov. https://heatisland.lbl.gov/coolscience/cool-walls

EPA. (2014, June 17). *Heat Island Impacts*. US EPA. https://www.epa.gov/heatislands/heat-island-impacts

Vishalakshi, K. P., Revathi, V., & Sivamurthy Reddy, S. (2018). Effect of type of coarse aggregate on the strength properties and fracture energy of normal and high strength concrete. *Engineering Fracture Mechanics*, *194*, 52–60. https://doi.org/10.1016/j.engfracmech.2018.02.029

PCA. (2024, August 12). *How Cement is Made - Portland Cement Association*. Portland Cement Association. https://www.cement.org/cement-concrete/how-cement-is-made/

The Editors of Encyclopedia Britannica. (2019). Heat. In *Encyclopædia Britannica*. https://www.britannica.com/science/heat

Alkali Silica Reaction - an overview | ScienceDirect Topics. (n.d.). Www.sciencedirect.com. https://www.sciencedirect.com/topics/engineering/alkali-silica-reaction

Buckling | mechanics. (n.d.). Encyclopedia Britannica. https://www.britannica.com/science/buckling

Concrete: Scientific Principles. (n.d.). Matse1.Matse.illinois.edu. https://matse1.matse.illinois.edu/concrete/prin.html

What is Water Made of? (n.d.). Www.fortworthtexas.gov. https://www.fortworthtexas.gov/departments/water/sdw/water-made

Barbhuiya, S., Das, B. B., & Idrees, M. (2024). Thermal energy storage in concrete: A comprehensive review on fundamentals, technology and sustainability. *Journal of Building Engineering*, *82*, 108302. https://doi.org/10.1016/j.jobe.2023.108302

Types od Concrete Mix for Any Project (n.d.) The Home Depot. https://www.homedepot.com/c/ab/types-of-concrete-mix-for-any-project/9ba683603be9fa5395fab901c07575fe

Cambridge Dictionary “Heat” *@CambridgeWords*, 22 Jan. 2025, dictionary.cambridge.org/us/dictionary/essential-british-english/heat. Accessed 25 Jan. 2025.
(*Lifeguarding Academy*, 2018) https://www.lifeguardingacademy.com/blog/heat-exhaustion-heat-stroke-how-to-stay-safe-this-summer

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