Proving The Effects of Surfaces on Urban Heat Island Effects

to

The Ohio Academy of Science

by

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January 27, 2025

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Abstract

Understanding Urban Heat Islands is very important to understanding urban planning in city life. Understanding this subject is not only important to science, but everyday life for the majority of people. In this study, we tested surface temperatures of natural and unnatural objects/areas to find what emits more heat, and why. This study was conducted using surfaces of grass, asphalt, concrete, and brick. Our independent variable was the surface type, while the dependent was surface temperature. Our results indicated that more natural surfaces, like grass, emit less heat as it cools down easier. The procedures of the study results in the idea of natural surfaces being able to emit less heat, while non natural ones emit more.

Table of Contents

Background Information

Everyday, people continue to take in pollutants while disregarding the harmful effects they carry. This is caused by effects such as urban heat island where urban areas continue to be increasingly harmful to the environment, encroaching on animal's natural habitats. While much is studied of the unfavorable effects of urban heat island and the emissions it brings, what truly correlates to this may not be as well known. From the effects of specific colors and surfaces have on these pollutants and exactly why they are emitted. This experiment will dive into the specifics of how separate surface areas affect urban heat islands by either amplifying or reducing the effects.

The urban heat island effect is where temperatures tend to stay higher in cities compared to that of rural areas. In urban areas, the surfaces tend to hold and absorb more heat, this is due to their unnatural nature whereas in rural areas much of the surface is greenery allowing transpiration to occur. This is where the plant's uptake of water is turned to water vapor then released back into the air, in turn cooling it down. That being said, in urban areas which tend to have more infrastructure than biodiversity, there is no natural way to cool the area causing higher temperatures overall(NASA). These aren't the only causes of the issue however, other factors include human activities and the weather too. As waste heat and carbon emissions can cause the effects to be amplified as well as calmer weather which allows more solar energy to reach the surface area. Furthermore, two different kinds of this effect exist, surface heat islands and atmospheric heat islands. Surface heat islands are due to different surfaces absorbing and emitting more heat such as roadways and rooftops, this effect is most apparent when the sub is at it's highest around noon. While atmospheric heat islands are a result of warmer air in urban areas, though this is not as intense of a problem as surface heat islands. In concern to the environment, this poses an issue as it increases energy consumption, carbon emissions, compromises health, and leads to a decrease in water quality.

This is due to an increase in the usage of air conditioners causing more fossil fuels to be burned overall polluting human and animal's health. As well as, causing fatal conditions to water as it becomes intolerable for marine environments causing them to die off. Altogether, urban heat island effect is causing an increase in harmful pollutants in the air while also causing a rise in urban health problems and animal deaths as well(United States Environmental Protection Agency).

Surfaces tend to absorb heat differently than each other, this can be due to the sensing of temperature, whether on its surface or back. The rate of heat transfer through surfaces is based on time variables and other factors such as weather, conditions, and temperature surrounding the material. " Heat transfer rates are generally deduced from time-varying temperature measurements and two assumptions; the heat transfer from the flow is one-dimensional into a material with known properties…the gauge or the skin of the model is a semi-infinite slab so that the temperature on the back surface remains constant with time,"(Science Direct). Along with the given information, other factors play in surface absorption such as specific heat capacity, thermal conductivity, color, and density. Knowing these factors, we can deduce that the different surfaces and different variables and temperatures absorb heat at different rates. Additionally, the inverse relationship between surface temperature and wavelengths of light makes it so as surface temperature increases, wavelengths will decrease. According to Wien's displacement law, "The blackbody radiation curve for different temperature peaks at a wavelength is inversely proportional to the temperature"(BYJUS). Therefore, surface temperatures absorb heat differently depending on many variables and laws.

Bringing urban heat island into this, different surfaces commonly found in cities are found to absorb and trap heat more efficiently than others. Such as, lightening streets are used to cool down the urban cities. These streets involve covering black asphalt streets, parking lots, and dark roofs with more reflective gray coating(NASA). The gray is reflective, so the wavelengths are reflected rather then converted into heat, therefore lightening the cities and simultaneously cooling them down. In contrast, building materials used in urban cities trap heat. These materials are called impervious surfaces, meaning water cannot flow through these objects like they normally would through a plant. Without these cycles of flowing through and evaporation, the surfaces cannot cool down. Unlike the impervious surfaces, plants and grasses take water up through their roots, which is then stored in stems and leaves, where they travel to small holes underneath the leaves. Then, liquid turns to water vapor released into the air, in the process of transpiration. Plants compared to building materials release cool air rather than trap in heat causing them to be a better candidate for helping cool cities rather than continuing to let the issue of overheating and carbon emissions continue.

Taking in these factors, this experiment is done to detail the connection between separate surface areas and the increase in urban heat island effects. As shown in the research above, urban heat island effects are due to the absence of greenery and an increased amount of infrastructure causing heat to be absorbed rather than released. Different surfaces and their differences in absorption of heat or conversion of heat also play a major role, along with urban cities' cooling and absorbing heat factors. This is of importance as the environment is increasingly dying as temperatures increase and substances pollute the environment. From effects such as acid rain and dying ecosystems, pollution caused by urban heat island negatively affects populations and their surroundings. For this experiment, certain surfaces are to be tested over a course of a week at peak sunlight to test their surface temperature and in turn how much heat they have absorbed and are emitting. With the hypothesis being, if a surface is more natural then it will not emit as much heat as it is able to evaporate water and cool the air better.

Experimental Design

Question: How do different surfaces affect urban heat island effects?

Hypothesis: If a surface is more natural then it will not emit as much heat as it is able to evaporate water and cool the air better.

Materials:

- Infrared Thermometer
- Weather Rite Tech System
- Cloud Data Sheet
- Surface Temperature Data Sheet

Procedure:

1. Gather your materials, an infrared thermometer and your cloud and surface temperature data sheets at about 11:00 am to 12:00 pm.
2. Record the temperature outside and the relative humidity using the Weather Rite.
3. Go outside to the area near the bus parking at Ottawa Hills High School.
4. Record the surface temperature of brick, asphalt, concrete, and grass.
5. Record the clouds using the cloud data sheets.
6. Repeat over the course of a week or more keeping time of day, thermometer, and areas constant throughout.

Independent Variable: Surface Type

Dependent Variable: Surface Temperature

Constants:

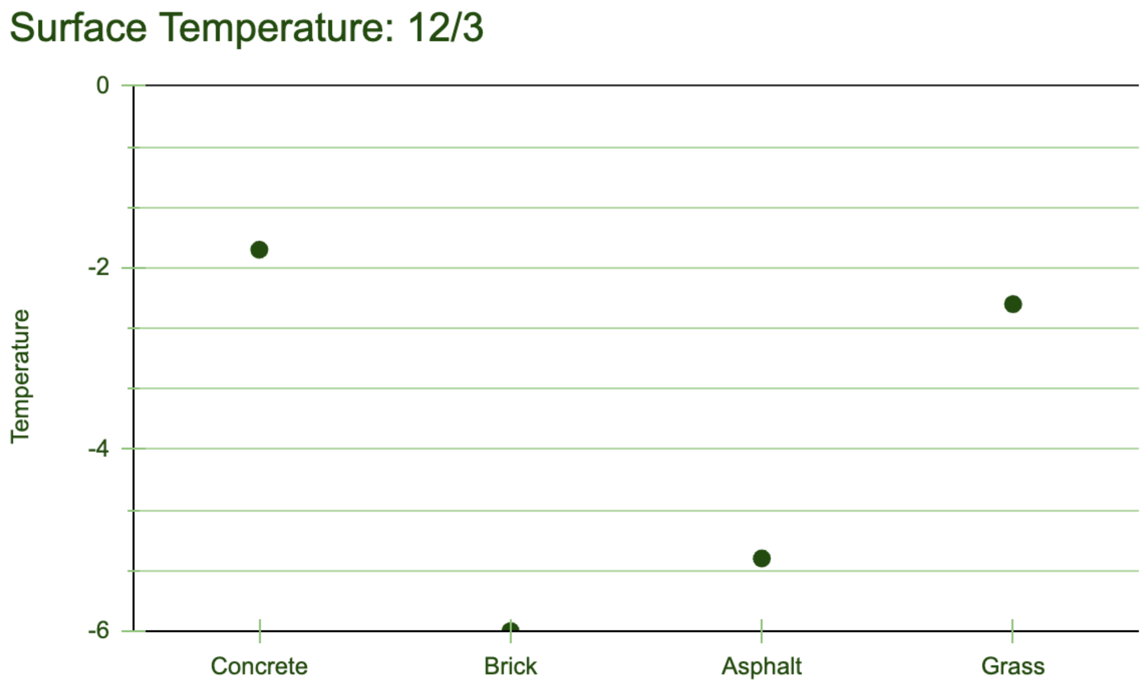
- Time of day
- Thermometer

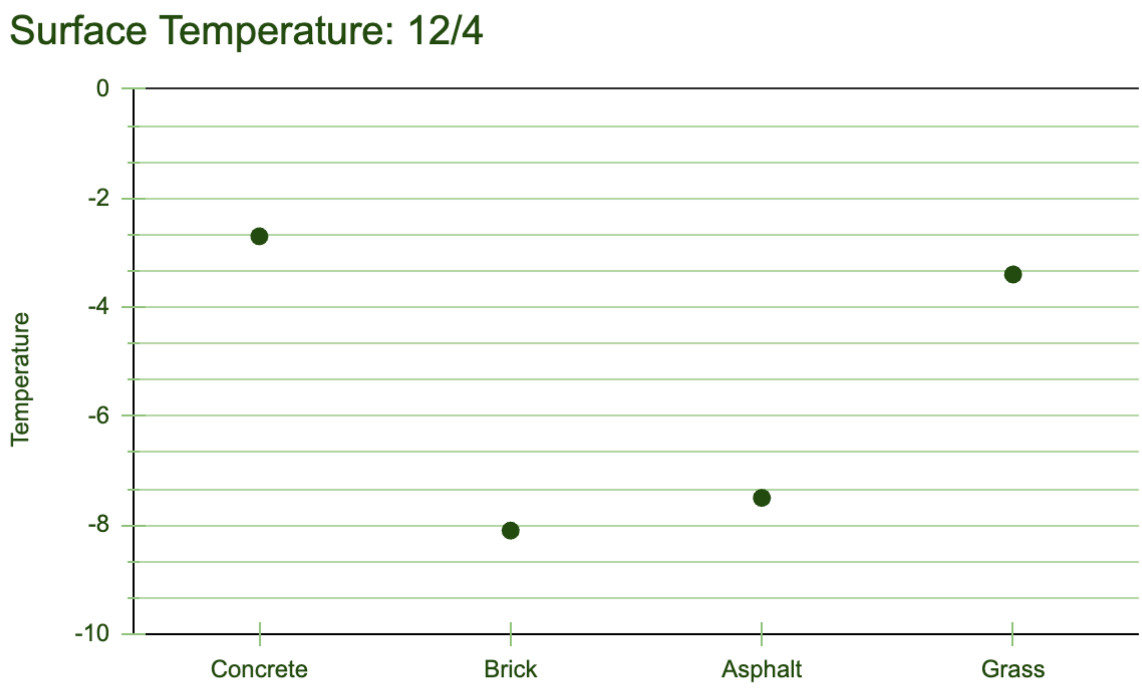
- Area being tested

Data Collection and Analysis:

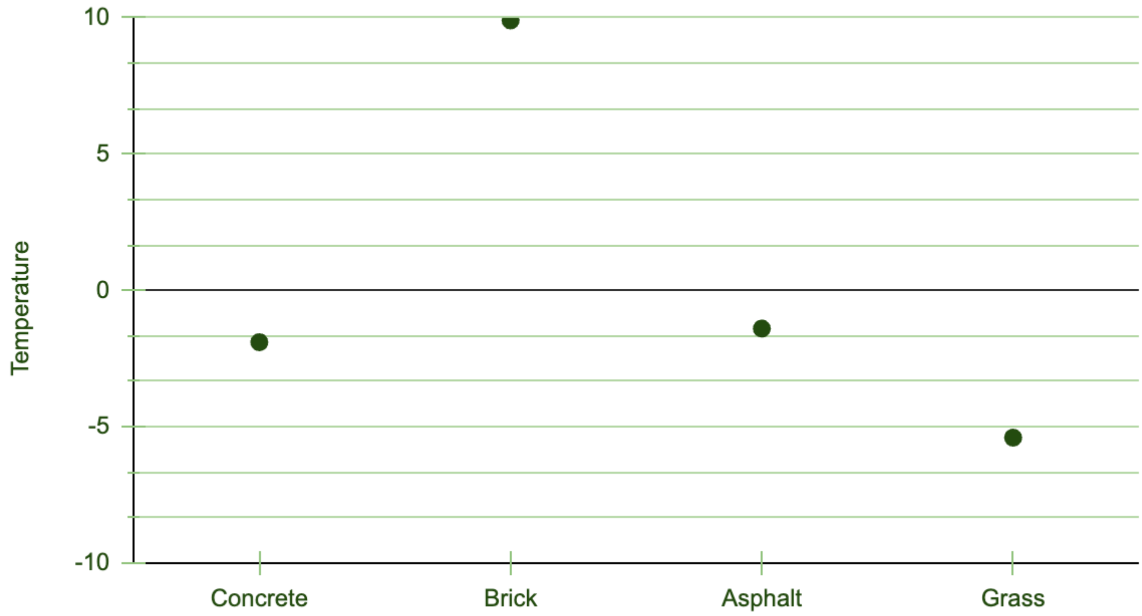
- Data is collected by using the infrared thermometer, and scanning the surfaces to collect the surface temperature.
- We then collect data on the clouds, and calculate how the sky and weather for the day is affecting surface temperature.
- There was about 8 trials/days where data was collected, so N=8.

Data

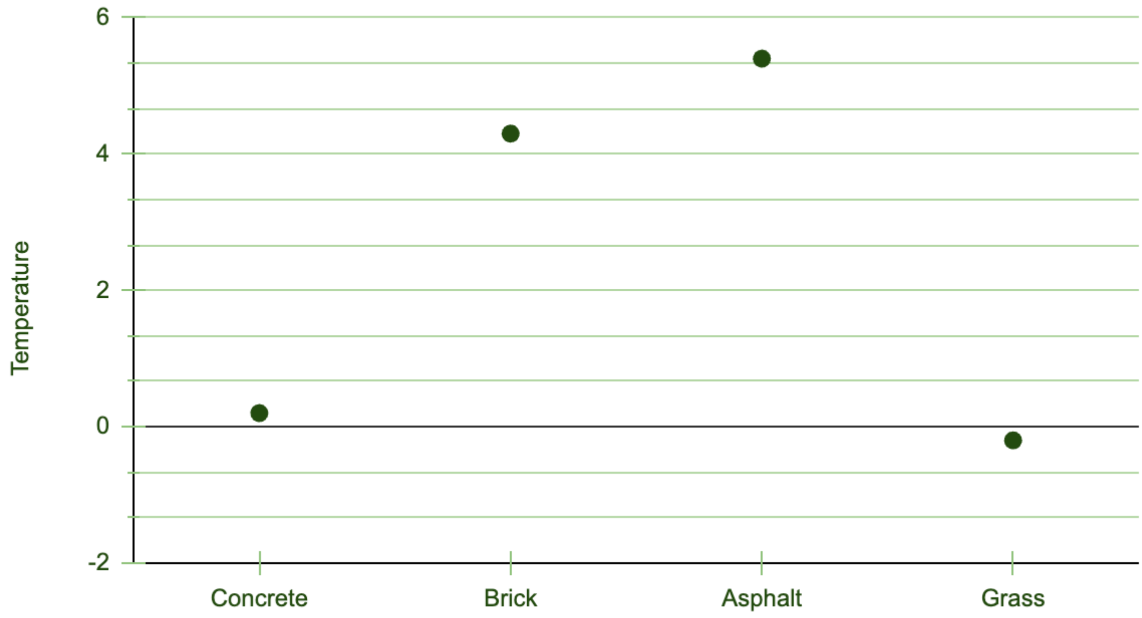

Surface Temperature: 12/3
Temperature
0
-2
-4
-6
Concrete
Brick
Asphalt
Grass


Surface Temperature: 12/4
Temperature
0
-2
-4
-6
-8
-10
Concrete
Brick
Asphalt
Grass

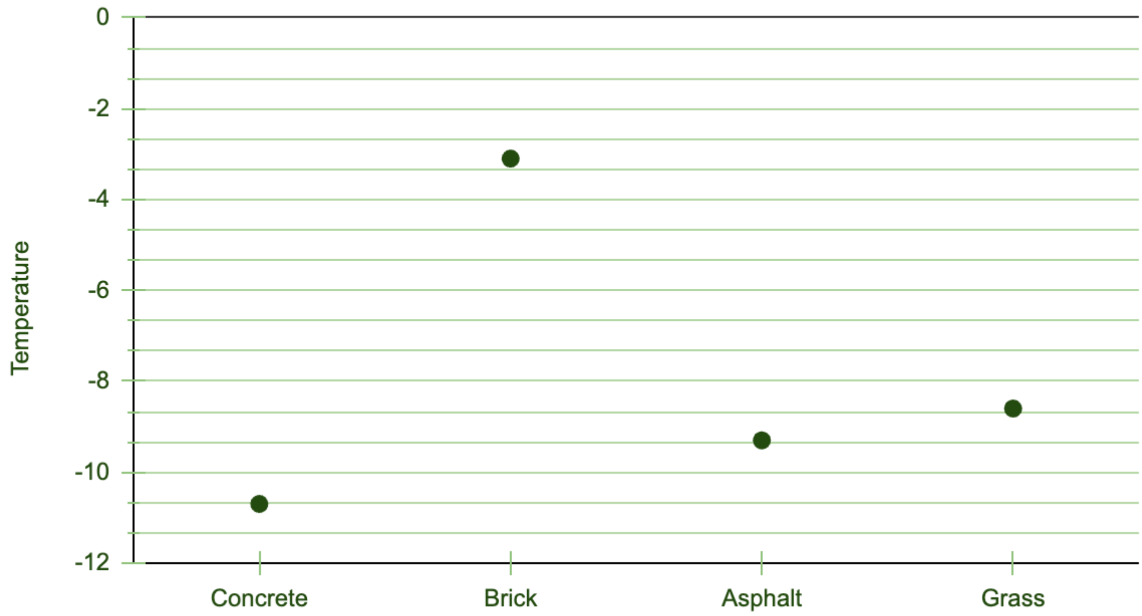
Surface Temperature: 12/5



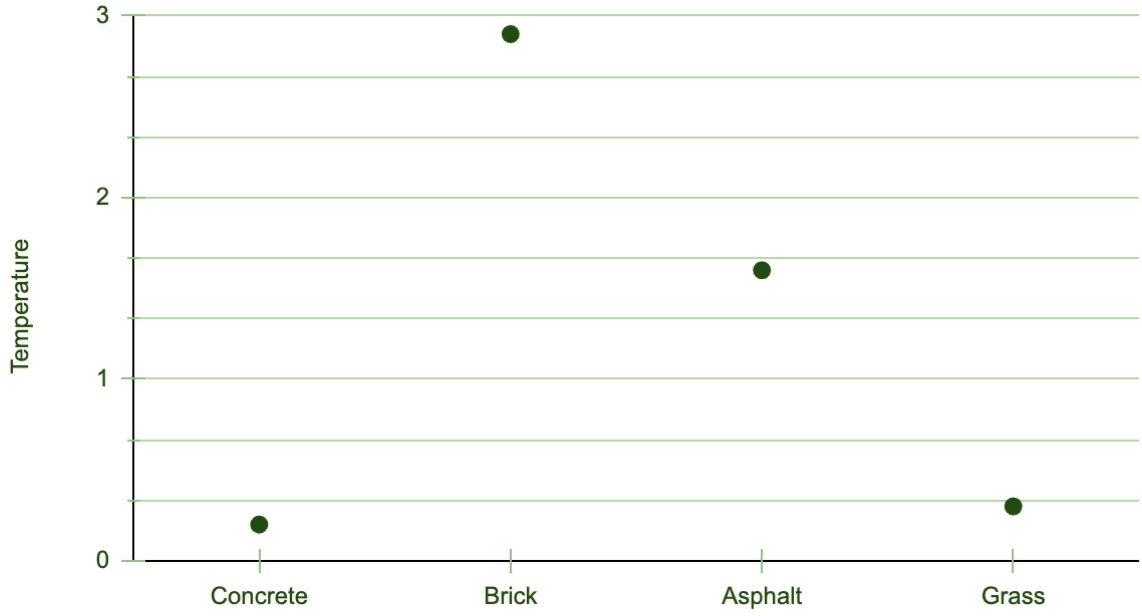
Surface Temperature: 12/8



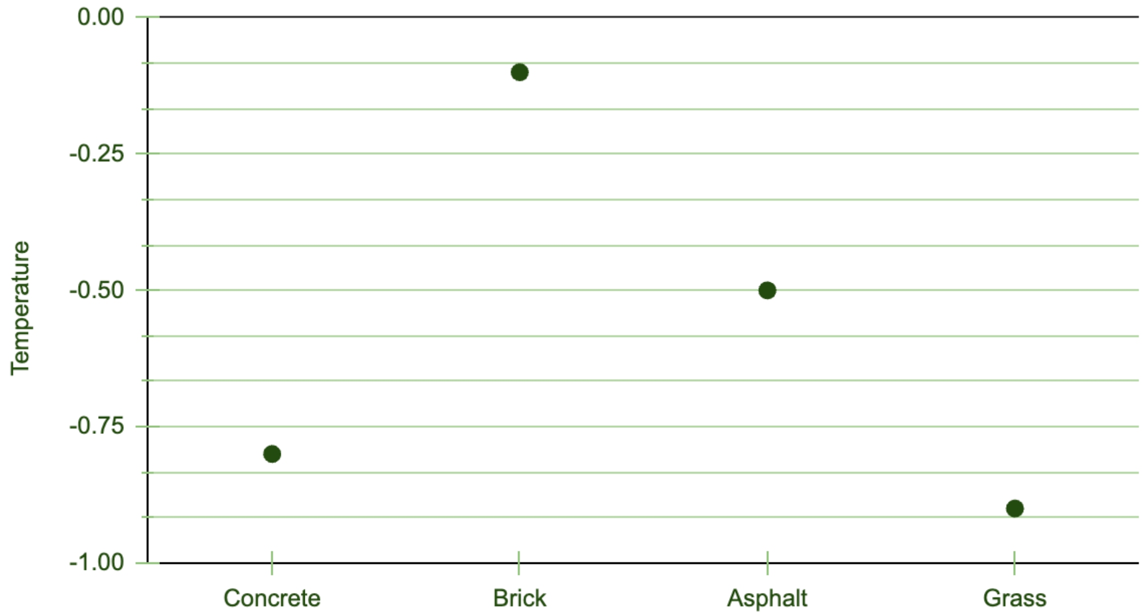
Surface Temperature: 12/9



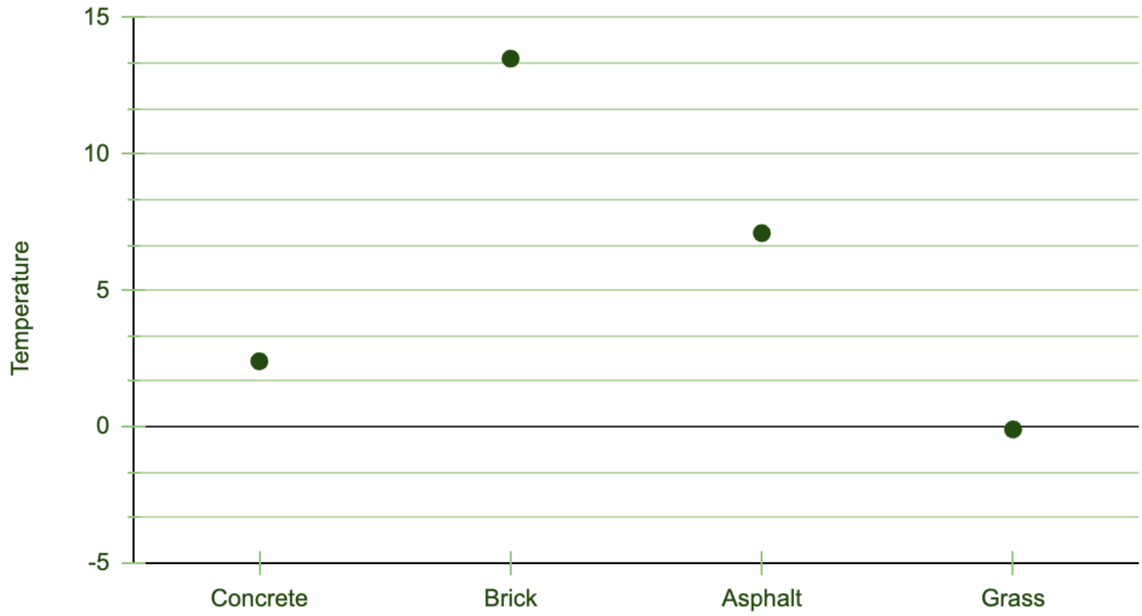
Surface Temperature: 12/10

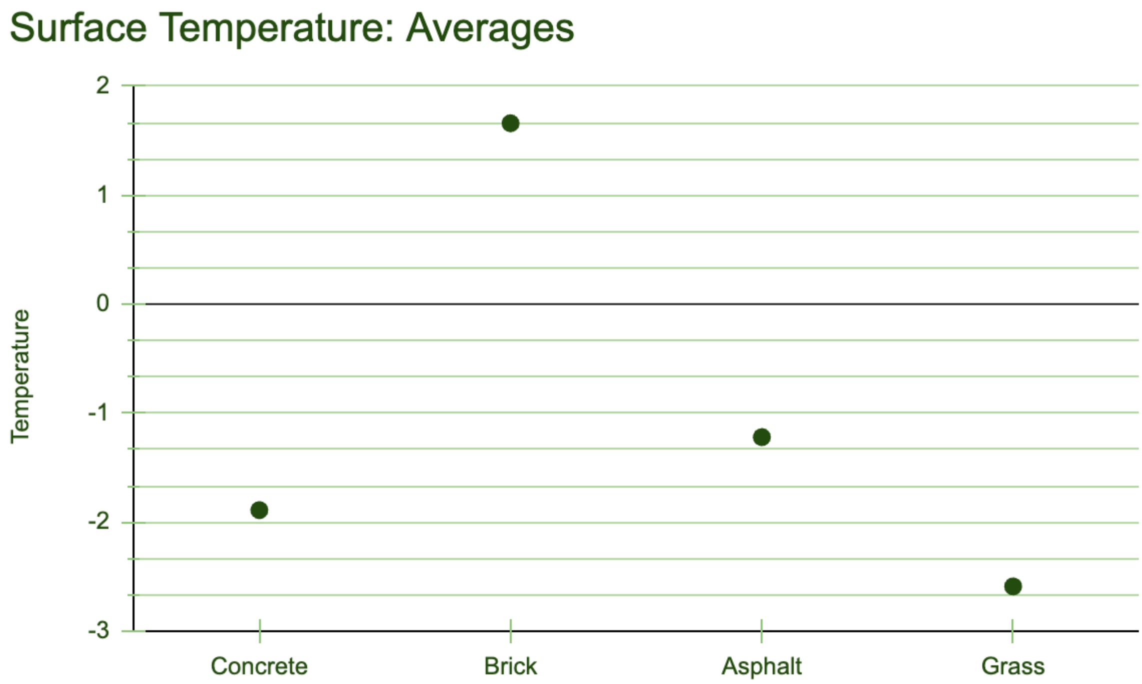


Surface Temperature: 12/11



Surface Temperature: 12/12





Surface Type	Concrete	Brick	Ashphalt	Grass
12/3	-1.8	-6	-5.2	-2.4
12/4	-2.7	-8.1	-7.5	-3.4
12/5	-1.9	9.9	-1.4	-5.4
12/6	0.2	4.3	5.4	-0.2
12/9	-10.7	-3.1	-9.3	-8.6
12/10	0.2	2.9	1.6	0.3
12/11	-0.8	-0.1	7.1	-0.1
12/12	2.4	13.5	-0.5	-0.9
Average Temp	-1.89	1.66	-1.23	-2.59
STD	3.9	7.52	5.88	3.11
SEMS	1.38	2.66	2.08	1.1
2 SEMS	2.76	5.32	4.16	2.2

In the graphs, asphalt and brick tended to emit more heat and fall higher on the graph while concrete and grass stayed on the lower side, usually occupying the negatives and low tens. However, the asphalt and brick were most likely on the high side due to their colors while concrete was probably due to it's color as well, grass most likely tended on the lower side to to it's composition and processes as a living organism. Some anomalies which occurred happened first on 12/3 when brick was significantly lower than the other surfaces, this does not have a good explanation due to weather and could simply be human error. This anomaly also happened the next day which could also mean there was something different going on as well. After this, most of the graphs stayed relatively the same with only slight changes between what was hottest and coldest. Though, on 12/9 grass did read as emitting more heat than asphalt though this can be assumed to be due to the amount of snow recorded on asphalt, 11mm, was greater than that of the grass, >10mm, causing the asphalt to trap in and emit less heat.

The results of our experiment have garnered similar results to those conducted in other parts of the world by other citizen scientists. Surfaces such as asphalt and concrete tended to have differences in temperature akin to that of our experimental results. Some things that may differ between these other studies however could include the location, cloud coverage, and season. Overall, our hypothesis was supported as on average natural surfaces like grass tended to emit less heat, read as colder, than unnatural surfaces such as concrete, brick, and asphalt. This most likely occurred not only due to the fact that grass is able to take in water cooling down it's surfaces while the other surfaces are unable to do so. Furthermore, as the experiment was conducted during winter with some days including snowfall, the grass, due to it's cooler temperature, would have snow stuck on top cooling it further. Whereas, the other three surfaces tested would melt the snow causing the surfaces to be less cold. Additionally, due to taking account of the cloud coverage and temperature each day, we can see the direct effects of the amount of cloud coverage over the temperature variations observed. Though, these data sheets only account for the reasoning in different temperatures between days to show the causes of why the ground temperatures may change in a short period of time. Supplementing the validity of the hypothesis.

Some possible experimental errors could be the thermometer not being the same distance from the ground per measurement, not tracking the cloud and sky patterns, or not recording accurate snow measurements. Some solutions could be to redo the temperature measurements, or to estimate the error using error bars on a graph, or to even calculate the difference between measurement errors. For the sky errors, we could look back on the weather for the day and estimate the cloud patterns, or re-track data. In another trial, we could record the snow more accurately if not done correctly, and use the other techniques given above. If a surface is more natural then it will not emit as much heat as it is able to evaporate water and cool the air better. Our hypothesis was backed by our data, however there may not be enough statistical differences between the concrete and grass to show a link between the naturality of a surface and it's surface temperature. Though, the hypothesis is still technically supported by our statistical averages, just not if you look day to day.

Conclusion

To end, our hypothesis was supported by our data as the results show that natural surfaces such as grass tended to emit less heat, while less natural surfaces such as concrete, brick, and asphalt tended to emit more. There is not enough statistical difference between grass and concrete, which could be due to its lighter color making the low difference between the two, as lighter colors absorb less heat. Some changes that could be made if this experiment were attempted again is to do a different array of places around the city. As well as, testing different surfaces such as different plants or soils and testing objects like gravel or rocks. For further investigation, we could test during snow storms, rain, or during the multitude of seasons and weather patterns throughout the year for a more thorough investigation. This research is important to our and others understandings of urban heat island effect, and can help give a better understanding of separate urban surfaces and how they emit heat. Furthermore, this research could potentially aid in urban planning as having the knowledge of how certain surfaces affect the overall environmental emissions a city puts out in this day and age is very important. For people who haven't ever tested this, it could broaden knowledge on the subject, and for those who have, it can open mindsets and bring more experiments or questions on the matter to surface.

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Acknowledgements

We would like to thank Dr. Kg for helping us with this assignment. She helped us by giving due dates to keep her students on track, and leaving helpful comments upon each document so we can revise and make the corrections needed.