Pervious Concrete Grotto: A Modular Evaporative Micro Climate

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PERVIOUS CONCRETE GROTTO

Deploying research on the role of evaporative cooling utilizing pervious concrete, this project attempts to formalize the relationship between module form, aggregate form, and evaporative capacity through a physical installation. Utilizing passive environmental principles, in which the performance of the wall is dictated by its environment, in this case the access to rainwater and wind, the installation is always "on." Intended as a system which could extend in all directions infinitely, utilizing Stan Allen's concept of the field condition, the physical installation is understood to be a smaller chunk of a larger possibility. Less of an enclosure and more of a generator of microclimate, this project attempts to connect issues of modularity constructability and microclimate.

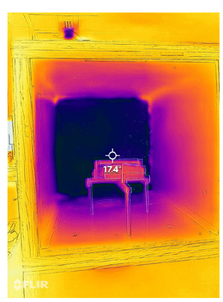
This relationship between form and performance is a dialectic expression of systems thinking writ large in its design. The rules which dictate aggregation also impact the evaporative performance of the elements. The wall consists of previous concrete precast elements which are tapered in plan and angled in section to produce variation through their aggregation. Their shape allows for the wall to turn depending on how it is stacked. Mirroring elements will produce a straight wall while repeating elements turn the wall, creating small spaces. These smaller spaces will necessarily experience greater cooling effects.

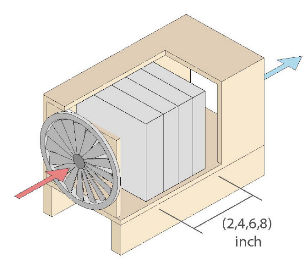
The wall is doused in rainwater which infiltrates deep into the wall through the pervious concrete. As wind and other natural ventilation processes push through the previous medium, evaporation is encouraged, cooling the concrete mass. The cooling of the wall produces a microclimate that is a byproduct of the ambient air temperature and humidity. The evaporative capacity of the wall is limited by that same air temperature and relative humidity. Thermal cameras and temperature sensors are used to document the heating and cooling of the wall throughout the year as it experiences different levels of precipitation and ambient environmental conditions. Testing of the wall is also completed with hand applied water.

With interest in passive environmental strategies, the pervious concrete grotto used modular concrete elements to produce a microclimate through water evaporation. It seeks to produce the cooling experience of a grotto, which acts as a datum to the ambient air temperature and relative humidity. It makes legible one possible expression of the relationship between passive material performance and the form of architecture.

PERVIOUS CONCRETE

Pervious concrete or as it's otherwise known no fines concrete, consists of aggregate cement and water in its most basic form. The lack of sand, or fines, results in a thinly coated aggregate with large gaps between each of the stones. These gaps allow air and water to flow freely. Previous concrete has been used to manage rainwater runoff. 1 Additionally, it has been used to absorb heat absorbed by rainwater runoff before it enters the ecosystem having novel effects on the impact of urban heat island effect. 2 The high thermal capacity of previous concrete provides A substantial thermal battery and suggest an opportunity for further utilization and integration of these systems





into buildings due to its unique characteristics of surface area and thermal mass. Additionally, pervious concrete differentiates itself from other previous technical and non-technical ceramics in the relative ease of its production, reduced number of ingredients and lack of specialized technology required for its creation. 3,4,5 One only needs a bucket and a shovel to produce rudimentary pervious concrete.

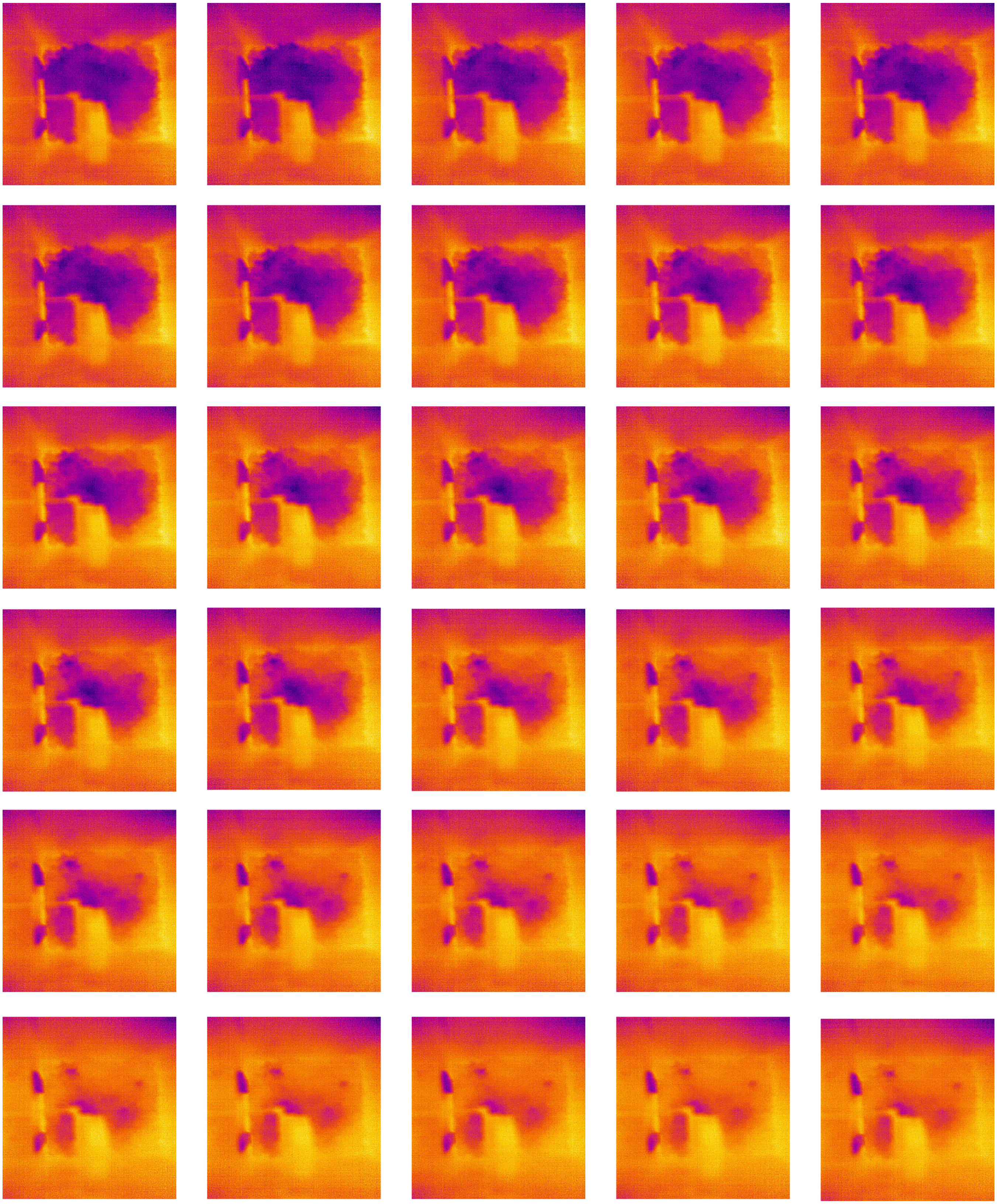


Figure 2. Sequential Thermal Images of pervious Blocks. Image Credit: Author

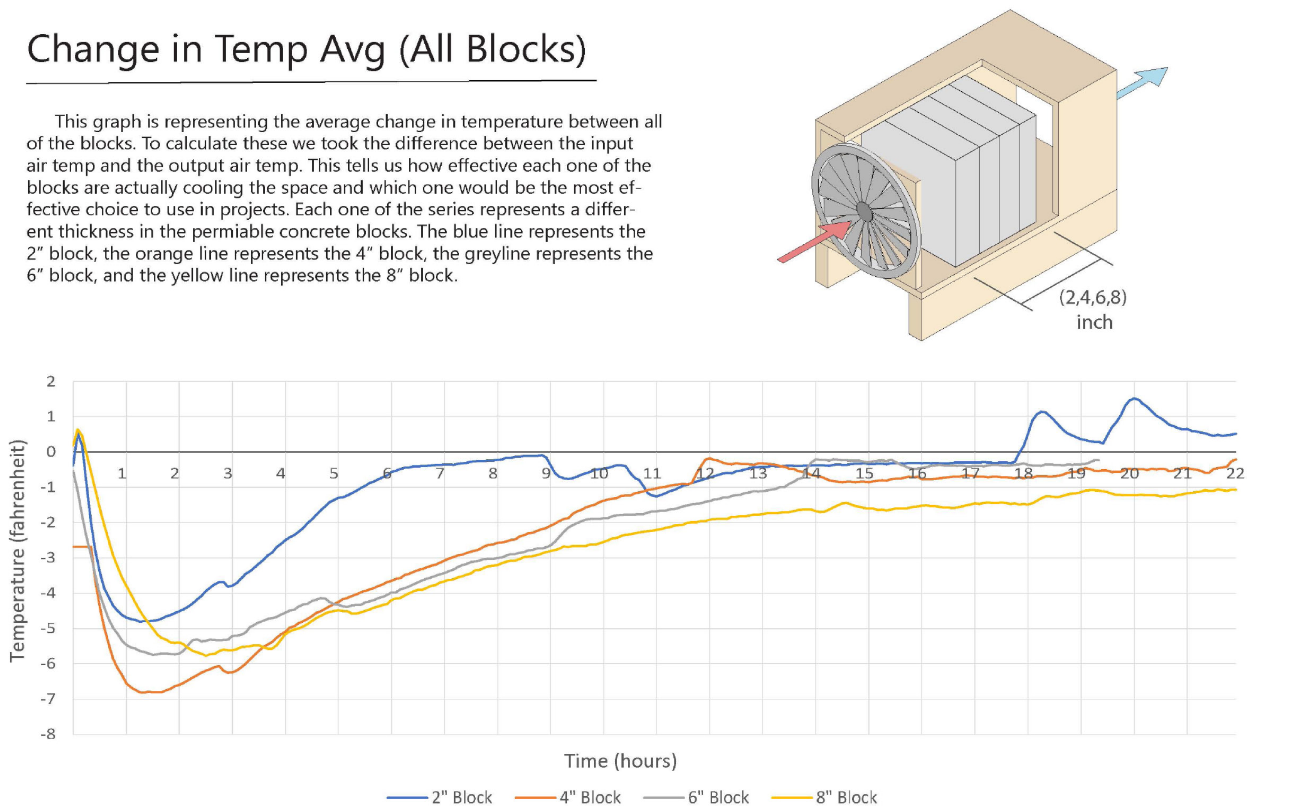


Figure 3. Changes in temperature. Image Credit: Author

SCALING PERFORMANCE TO MATERIAL THICKNESS

To further understand the relationship of thickness to performance of thermal mass and evaporative cooling, blocks of pervious concrete were saturated with water and then forced to evaporatively dry to lower their temperatures. Research assistants built a testing apparatus which drove air through a pervious concrete block. Each block was first saturated with water and then placed directly into the test box. This analysis was integrated into several future projects related to pervious concrete as an evaporative medium, and specifically the pervious concrete grotto installation.

10" x 10" blocks of pervious concrete at 2", 4", 6", and 8" thicknesses were tested by soaking them in water and then driving air across the pervious medium. To drive the air across the pervious medium a 12-volt fan was used. Sensors were placed on the input and output sides of the pervious concrete blocks. Using these sensors, ambient input air temperatures and relative humidities were tracked over the course of 24 hours. Additionally, output air temperatures and relative humidities were measured and used to determine the performance of each block by subtracting from the ambient input air temperature and relative humidities. Each block was tested three times and their temperatures averaged. The blocks were tested with a controlled environment at 72F and 50% RH.

This data was graphed out to allow for comparison between the blocks. The 2" block had a delta output air temperature of -5F from ambient and returned to ambient temperature after 6 hours. The 4" block had a delta output air temperature of -7F from ambient and returned to ambient temperature after 12 hours. The 6" blocks had a delta output temperature of -6F from ambient and returned to ambient temperature after 14 hours. The 8" blocks had a delta output temperature of -6F from ambient and did not return to ambient temperature during the 24-hour test period. This experiment found 4-6" blocks to perform equally in terms of low temperature and duration with which that temperature is provided.

THE MODULE

Each module was designed to taper both in plan and section. The tapering provided a variable for modulating the plan of the wall. Not inconsequentially, this tapering also provided a significant draft angle allowing for easy removal of the module from the mold. The mold consisting of a CNC fabricated plywood covered in phenolic resin. Included in the mold were several preset PVC pipes which would later be used to post tension the wall together. Solid concrete was used at the back side of the mold to allow for secure anchoring of the pick point of each module. In addition to providing the structural capacity required for the pick point this solid concrete also provides an visual que for the wall flipping orientations. A single person could remove each

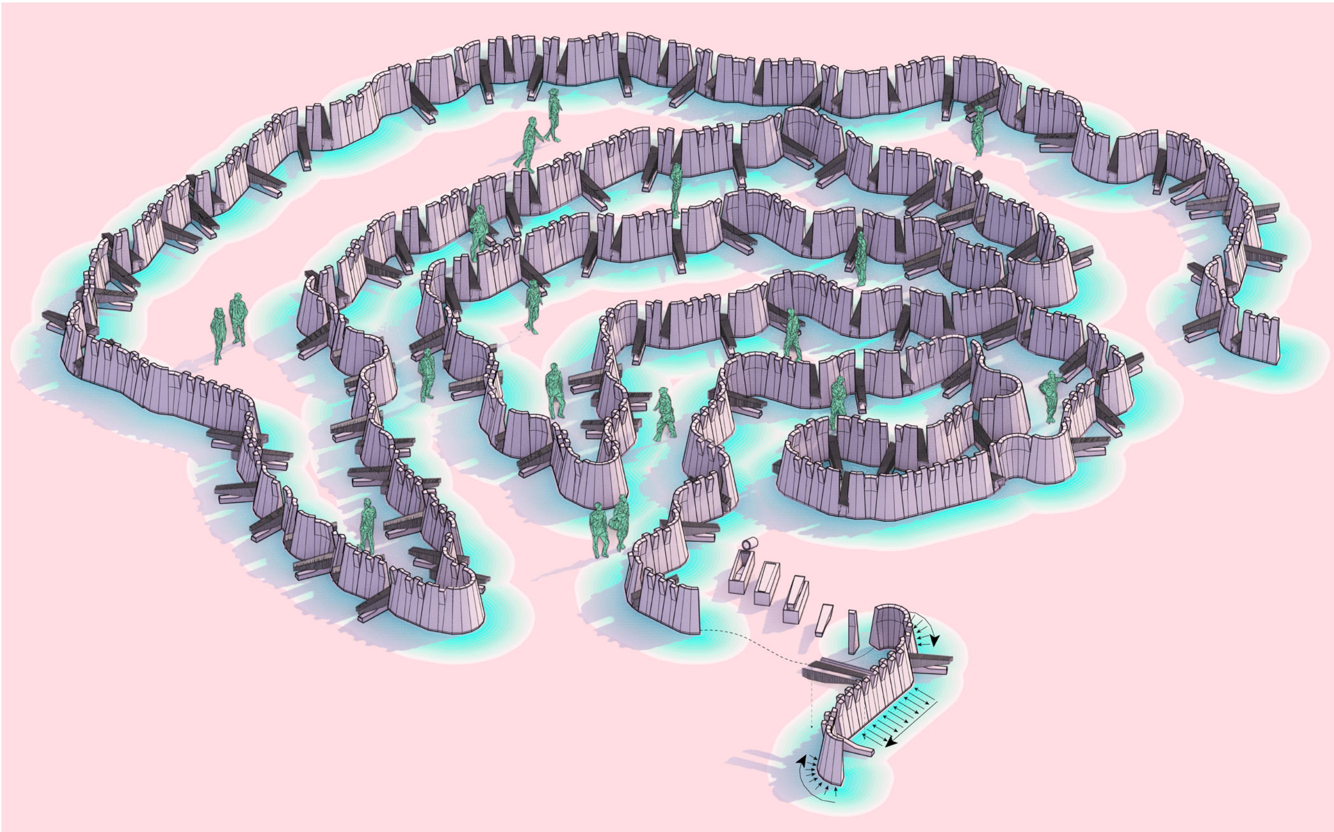


Figure 4. Stan Allen's concept of the field condition was important in developing the module. Image credit: Author

module with an engine lift and then use the same engine lift to place the module in its designed position.

Stacking modules without flipping them results in a curved wall; the top of the wall remained continuous. Alternating stacking modules by flipping them results in a straight wall; the top of the wall produces a feathered like condition. Preset PVC pipe holes used for post tensioning a wall together were placed in such a way to allow for these two aggregation techniques. To produce a bench or seating area modules are simply tipped onto their side with an urban harvested white oak bench mounted to them.

THE GROTTO

The idea of a grotto, both artificial and natural, was to provide a thermal escape, shelter, or pleasure relative to the environment elsewhere. Whether used for the storing of perishable goods, or relaxation, the ability of the grotto to provide cooling was essential to its understanding in contemporary society and antiquity. The pervious concrete grotto presented in this paper seeks to again provide cooling through evaporation. The presence of water, often associated with traditional grottos, continues, and is maintained through the function of evaporative cooling present in this installation. The relative dampness found in the cave-like grottoes of antiquity is also present in this installation, while it skews the aesthetics of the cave, it maintains

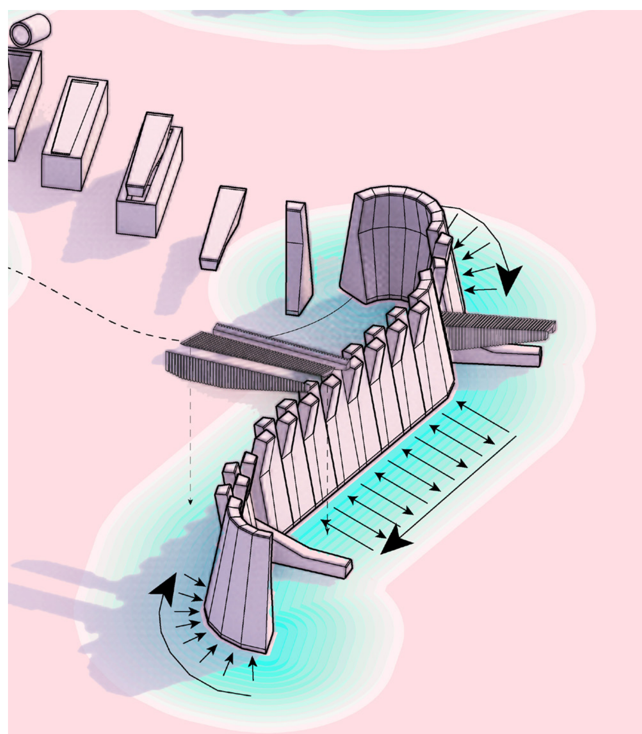


Figure 5. Zoom in on field condition drawing. Image Credit: Author

Figure 6. Pervious concrete must be wrapped in plastic to cure properly. Modules are moved with preset anchoring points. To remove the pieces an engine lift was used. Demolding was easy given the tapered form of the module.. Image Credit: Author

Figure 7. With an interest in modularity a mold is developed that allows for variability in the aggregation. Image Credit: Author

its essence. The form and function of these modules does not attempt to visually recreate the grotto but to functionally recreate the grotto and suggest a passive environmental strategy for contemporary design.

ENDNOTES

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Figure 8. Completed wall, Image Credit: Author

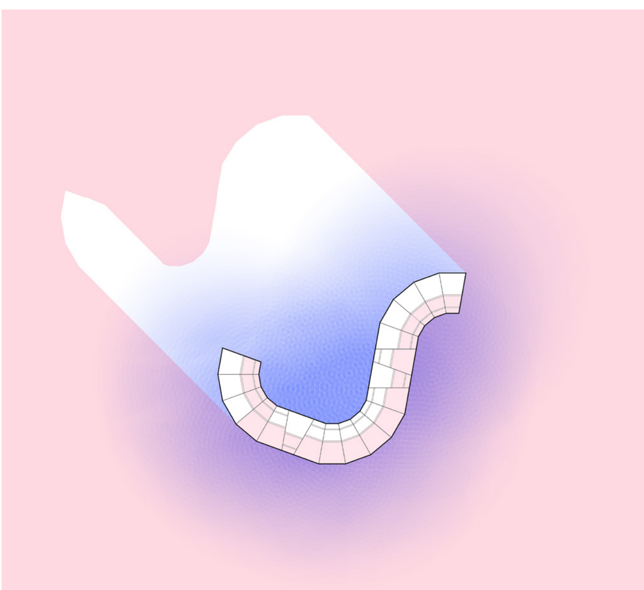

Figure 9. Plan showing the shadow and radiant enviroment produced by a water saturated wall. Image Credit: Author

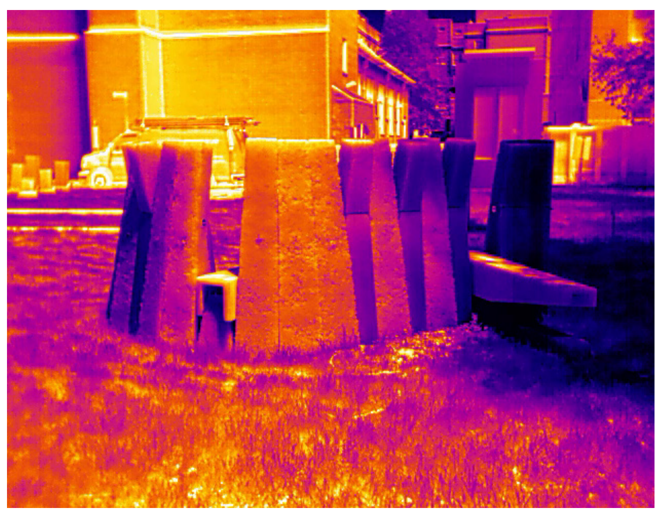

Figure 10. Thermal Imagery of Cooling wall, Image Credit: Author