Infill Synthetic Turf Field Heat Island Effect
White Paper
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Introduction:

Heat Island Effect is a complex matrix of energy transfer in built-up areas, which through a combination of; heat storage within urban materials, reflective behavior from those materials, and release of the heat stored within those materials, results in a warming of the air as compared to that of surrounding non built-up areas. This warming occurs within the surfaces and within the air canopy. According to the Federal Environmental Protection Agency small cities experiencing heat island effect have a daytime increase of 2°F to 6°F and a nighttime temperature increase of as much as 22°F. Heat island effect results in increased energy consumption and greenhouse gas pollution, increases in heat related illnesses, warming of runoff waters impacting water quality, and warming of waterbody and wetland habitats.

The advent of synthetic turf and its tendency to become hot during the midday of summer months has increased concerns relating to its potential contribution to heat island effect. For many years users of synthetic turf have voiced concerns relating to how hot these fields get during peak day solar radiation, during the summer months. These surfaces can become too hot to play on. Based on temperature data from a wide array of sources, synthetic turf surface temperatures during peak day solar radiation, during June, July, and August can be elevated over adjacent air temperature by as much as 75°F. This temperature increase is significant, but does infill synthetic turf contribute to a community's heat island effect?

Solar Radiation Properties:

To understand if the summer heating of synthetic turf constitutes a localized heat island effect we must better understand the energy transfer that takes place in commonly known heat island materials and how they relate to synthetic turf grass. In 2009 a paper entitled, "Modeling the Thermal Effects of Artificial Turf on the Urban Environment by Neda Yaghoobian and Jan Kleissl", published in the Journal of Applied Meteorology and Climatology, attempted to address that specific issue. They modeled the effects of artificial turf on the urban canopy layer. They utilized energy balance, air and surface temperatures, and building cooling loads generated from common ground surface materials such as: asphalt, concrete, and grass, using heat transfer modeling of radiation, convection, and conduction. Temperatures of Urban Facets in 3D (TUF3D) software model was used on clear summer day conditions in San Diego, California to evaluate this potential.

Inputs into this model included thermal and radiative properties of natural grass, artificial turf, concrete, and asphalt. Natural turf grass was included as a baseline goal for a non-heat island surface. Concrete and asphalt were included due to their known thermal behavior in urban environments. The specific radiative properties included; thermal conductivity, heat capacity, momentum roughness, thermal roughness, albedo, and emissivity. Two of the properties; heat capacity and albedo stood out as prime properties in this study. Albedo is proportion of radiation that is reflected up from a surface and includes both short and longwave radiation. Heat capacity is the amount of heat needed to raise a material temperature one degree. These two properties become critical and represent energy reflected up and into the canopy during the day, warming vertical surfaces, and stored heat released into the canopy at night. Also included in the model was the mass of the various materials. Of the materials evaluated concrete and asphalt had a high mass and the ability to store more heat energy during the day for release at night. Artificial turf and natural turf grass have low mass and cannot store large amounts of heat and therefore have very limited heat release at night.

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Light radiation from the sun arrives to the earth's surface in ultra violet, visible, and infrared spectrums. In that order, they represent shortest to longest wave lengths. The shorter the wave length, the higher the amplitude, and the hotter the light. The opposite is true for long wave radiation. Of the four materials artificial turf has the lowest albedo and reflects the lowest amount of heat energy during the day.

The results of the model were a surprise to those participating in the study. They found the lack of heat mass, inability to store heat, and the low albedo resulted in a slight decrease in energy required to cool buildings during both day and night. The low albedo of artificial turf results in a reduction of shortwave radiation reflecting from the surface to the building walls and an increase in the cooler longwave radiation reflecting to the same walls. The end results is that based on their analysis synthetic turf does not contribute to heat island effects in a community.

At the time of the study they did not have field data that could verify these properties.

<u>Synthetic Turf Temperature Field Data:</u>

As part of project closeout work for some of JJA Sports New England, during summer months a series of temperatures were taken to assess temperature difference around, on the surface, and within the synthetic turf system. Temperatures were taken when completion dates fit with the summer window between 2007 and 2009 for general knowledge. These fields were new fields and had not undergone fiber breakdown typical of older fields. Infill material was generally covering the newer fibers and limited infill was exposed to the sun.

More recently thermal evaluation was been completed on fields in Westford and Chelmsford, Massachusetts in support of this document. These fields had significant fiber breakdown and infill material was somewhat exposed due to a loss of fiber mass.

Under both data collection efforts air temperatures were obtained off the field at a 3 foot height above grade. This location was, more often than not, a grass area off from the edge of the field. The next air temperature was generally within the synthetic turf field, away from edge of the turf, at a similar 3 foot height above grade. More recently, where a track encompassed the synthetic turf field, an air temperature reading was obtained in the center of the track lanes at a 3 foot above grade. The next reading included an air temperature reading obtained at a height of 1 foot height above the field. A surface temperature reading and a reading within the infill material were the final temperature readings.

Conditions varied on each reading day. Early on in the process, it was quickly determined that cloud cover blocking the sun effectively reduced readings at all heights and in all locations. As a reference description, where surface temperatures were very hot to touch, cloud cover rapidly brought surface temperature down to a warm temperature. This was consistent with relatively low surface weight, and low heat capacity of fibers exposed to solar radiation. Fibers stored very little heat in their small mass, and that heat quickly dissipated when the energy source was removed.

Generally all fields followed a similar trend in relative temperatures from reading location to reading location. Off field and on field at the 3 foot height tended to be within 2°F. Temperatures at the 1 foot height above the field ranged from equal, to as much as 6 degrees above the 3 foot height reading. The average delta between these two readings was plus 4°F. The difference between the 1 foot reading and the surface ranged from 1 degree obtained under a summer time 7:30 pm reading to as much as 56

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degrees higher on the surface. Infill temperatures averaged approximately 15° higher than the reading at the 1 foot height. As the sun dropped in the evening temperatures generally balanced with air temperatures. The infill did retain its heat longer, but was on a dropping trend with surface temperatures being lower than the infill below. See table 1 below.

These values represent thermal characteristics similar to non-heat island conditions where air temperatures above the surface in question closely match those of the air off surface and the exposed fiber provides no heat capacity to warm evening conditions.

Location	Date	Time	Weather Conditions	Product and Infill Material	Air Temp Off Field (°F)	Air Temp Track +3' (°F)	Air Temp 3 Feet Above Field (°F)	Air Temp 1 Foot Above Field (°F)	Air temp at Turf Field Surface (°F)	Infill Material Temp 1/8" to 1/4" Below Surface (°F)
Westford Academy Stadium Field	6/19/20	7:30 AM	Light Clouds Light Wind	FieldTurf/Sand and SBR	82.8	83.8	82.8	82.4	81.7	92.5
Westford Academy Stadium Field	6/19/20	5:30 AM	Light Clouds Light Wind	FieldTurf/Sand and SBR	88.9	91.6	90.0	91.2	119.5	104.9
Westford Academy Stadium Field	6/19/20	3:30 PM	Light Clouds Light Wind	FieldTurf/Sand and SBR	90.7	90.7	93.2	95.5	142.5	108.2
Westford Academy Stadium Field	6/19/20	1:30 PM	Light Clouds Light Wind	FieldTurf/Sand and SBR	91.6	92.3	94.7	100.2	155.7	124.3
Chelmsford McCarthy Middle School	6/6/20	1:00 PM	Windy with Clear	Sprinturf/Sand and SBR	91.5		91.8	93.2	149.4	118.2
Chelmsford McCarthy Middle School	6/5/2	3:00 PM	Windy with Wispy Cloud Cover	Sprinturf/Sand and SBR	82.0		84.7	86.3	103.6	91.8
Westford Nutting Road Fields	6/5/20	3:20 PM	Windy with Clear Skies	Field Turf/Sand and SBR	86.1		87.3	93.1	113.5	104.9
Danbury Rogers Park	6/22/09	12:20 PM	Cloudy	Field Turf/Sand and SBR			73.6	76.6	99.7	82.6
Worcester Polytech Alumni Field	8/7/2007	2:15 OM	Clear	Field Turf/Sand and SBR	93.0		95.0		133.0	105.0
Waterbury Field	9/4/07	11:15 AM	Clear	Sprinturf/Sand and SBR	79.5		79.5	86.1	116.8	93.8
Waterbury Field	9/5/2007	12:15 PM	Clear	Sprinturf/Sand and SBR	84.8		84.8	86.1	126.0	91.5
Waterbury Field	9/6/2007	1:00 AM	Clear	Sprinturf/Sand and SBR	86.0		86.1	95.0	136.1	94.0
Walpole High School Turco Field	10/16/07	2"00 PM	Clear	A-Turf/Sand and SBR	63.0		67.0	73.0	98.0	
Average Values					85.2	91.5	86.5	90.7	126.7	104.3

Table 1: Synthetic Turf Field Thermal Summary Data

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Heat Impacts to Rainwater and Surrounding Waterbodies:

Rainwater temperatures increase as surface flow travels along hotter temperature surfaces during the summer season. The hotter the day and the later into the day a rain event takes place, the higher the potential for the heat capacity of the receiving surface to raise the water temperature. Surfaces such as concrete and asphalt have a high heat capacity causing a buildup in the materials heat storage during the summer days. Rainwater can pull this heat from a surface and raise the temperature of the runoff. These raised water temperatures can impact the temperature and water quality of waterbodies downstream of these surfaces.

As discussed above, a critical aspect of synthetic turf fibers as it relates to heat island impacts is that these fibers have a very small mass and a low heat capacity. With that, they have very little heat mass to alter the temperature of rainwater as it strikes the ground and comes in contact with the fibers. Further and equally important, as cloud cover, which is typical with rain events, blocks the sun the surface temperature drops rapidly.

The upper portion of the infill below and within the fibers does warm by days end. The lower portion, due to the crumb rubber having insulating value, maintains its temperature near ground temperature. A bigger factor is the cross-section design of the field and drainage below. Our recommendation is that a resilient drainage pad, that provides insulating capacity, sit below the carpet. Any potential warming of the surface during summer is prevented from going more than an inch or so into the surface by this insulating surface. Below that is typically either a subsurface detention of a combination or detention and infiltration.

Rainfall events of 0.5 inch or less produce almost no surface runoff from synthetic turf fields. This is due to rain volume filling voids in the infill material. As this water passes through this medium it warms. After passing through the turf, rainwater enters the piping network and subsurface detention system, where it will be cooled by drainage stone which will be at a ground temperature of approximately 70°F. The mass of the drainage stone is far higher than that of rainwater and results in a cooling effect. By the time it leaves the subsurface system, the water temperature will be generally equal to the ground temperature at 3 feet below grade. Because of this the system will not result in an increase in water temperatures released into stormwater drainage systems.

Conclusions:

Infill synthetic turf playing fields do get very hot during the summer months, but this material does not result in a localized heat island effect. The combination of the fiber's small mass, low heat capacity and very low albedo, create conditions in the TUF3D model that actually result in a very slight decrease in the energy required to cool buildings during the evenings. From a water quality perspective, again the fiber's small mass, low heat capacity, and very low albedo limit the potential for heat buildup in surfaces that would cause detrimental water temperatures and downstream water quality.

Still, it is strongly recommended that field users consider surface temperatures when scheduling play on the surface during summer months. Providing shade shelters, water for hydration, and possible misting stations should be standard practice. Not scheduling use during midday is also recommended. It is not recommended that water be used to cool the surface because it results in high humidity. If you desire to cool something, cool the players.

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