Measuring the Effect of Thermal Radiation on Pedestrian Comfort

Research Project for the Dwight D. Eisenhower HIS Fellowship Program

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Abstract:

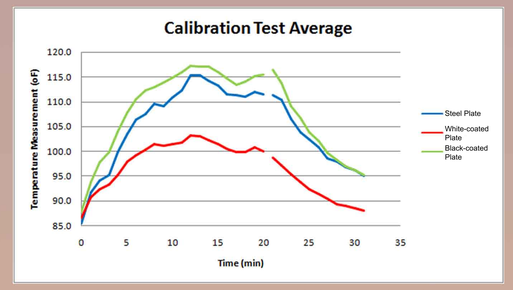
Puerto Rico is a moderately sized island in the Caribbean Sea; a location characterized by direct and consistent solar exposure throughout the year. Such consistent exposure to solar radiation would naturally have a greater impact on the thermal comfort of pedestrian than it would in more temperate zones. The objective of this research is the development of a methodology to measure the levels of thermal radiation affecting pedestrian facilities and to directly relate these results to pedestrian thermal comfort.

The measurement of temperature should take into consideration three distinct sources of thermal radiation, all of which have a direct effect over pedestrian facilities: a) the direct solar radiation from the sun, b) the thermal radiation that is emitted from the heated pavement surface, and c) the thermal radiation resulting from vehicular activity in close proximity to pedestrian facilities. A plate thermometer was designed and used for temperature measurement. The use of a plate thermometer allows measurement of thermal radiation emitted from a single angle and simultaneously isolates the rest of the device. Sites with high and low amount of shadow were selected, in order to quantitatively assess the effect of the shadow in pedestrian comfort. The final step is the data analysis to develop empirical relations between the collected data and literature recommended standards for outdoor comfort. The obtained data should provide useful information for pedestrian facilities design in areas or regions with high levels of solar exposure, and for future development of pedestrian studies in regions that are exposed to microclimates.

Instrument Calibration:

Calibration consists of using three 1' x 1' steel plates, each of different surface textures. The plates are heated under direct sunlight for 20 minutes, with measurements taken every minute. Afterwards they are left to cool for 10 minutes with measurements taken each minute.

Plates during calibration process



Average results of calibration test show that the black plate was heated more than a normal steel plate while the white plate was heated a lot less.

Project Scope and Methodology:

1. Design, testing and calibration of a device for measuring temperature effects due to thermal radiation striking a spot. The radiation is due to 3 distinct sources: solar radiation, surface radiation from the concrete pavement and radiation due to vehicular activity.

2. Select a site with varying tree penetrated shadow conditions: fully covered, partially filtered and no cover.

3. Perform measurment of temperature variations in these three conditions at different times during the day.

4. Based on results recommendations can be made on how to alter pedestrian facilities design guidelines in order to incorporate thermal radiation and ways to deal with it.

The design of experiment can be divided into four steps that need to be taken in order to successfully measure temperatures due to radiation.

a. Site Selection: The selected site is a typical man-made sidewalk in an urban context which presents the three aforementioned exposure conditions.

b. Instrumentation Selection and Design: An infrared thermometer is used to measure temperatures resulting from thermal radiation emitted from pavement surfaces and active vehicles. For measuring the temperature due to solar radiation a device was designed based on a steel plate which was isolated on all sides but one.

c. Instrument Calibration: Three types of plates were tested: one painted completely white, one painted completely black and one in its natural state. The plates where exposed to sunlight for a period of 20 minutes then allowed to cool for 10 minutes.

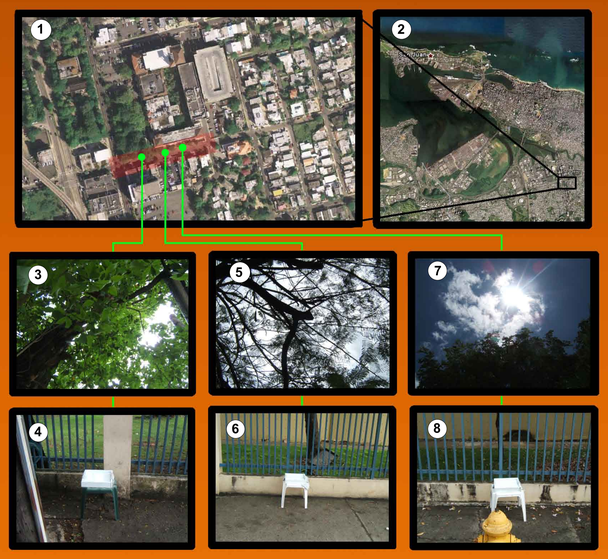
d. Temperature Measurement: Temperature measurements were conducted at 3 measurement stations. (Station 1 - under complete shade, Station 2 - in an area where sunlight filters through, Station 3 - under complete sunlight) Measurements were taken in intervals of 5 minutes for 2 hours, once from 9AM to 11AM, once from noon to 2PM and once from 3PM to 5PM.

Objective:

This research project is meant to study the effect of thermal radiation on pedestrian comfort, pedestrian facility design, and the determination of any existing relationship that can adequately relate them. The study stays within the boundaries of studying the effect of components of thermal comfort, but limits it to the effect of thermal radiation exclusively. The final aim is to directly relate thermal radiation levels with pedestrian facility design.

Study Site:

The selected site is the pedestrian facility of Jose Marti street, located adjacent to the Polytechnic University of Puerto Rico's campus. This site contains 3 spots where the level of solar exposure vary accordingly, and it is also in proximity to the heavy traffic of the PR-25.



Preliminary Results:

White Plate - Morning Temperature Measurements

Time (military)	Temperature Readings (°F)						Weather Condition
	Station 1 (full shade)		Station 2 (filtering sunlight)		Station 3 (full sunlight)		
	Plate Reading	Surface Radiation	Plate Reading	Surface Radiation	Plate Reading	Surface Radiation	
9:00	86.1	88.2	84.8	90.8	86.0	101.8	---
9:05	85.2	85.5	87.0	89.0	96.6	103.1	Sunny
9:10	86.7	86.4	91.0	90.9	99.9	106.9	Sunny
9:15	87.1	85.7	93.1	92.4	100.1	107.0	Sunny
9:20	86.7	84.6	91.7	94.0	101.1	106.5	Sunny
9:25	86.7	83.8	91.5	93.0	102.3	107.6	Sunny
9:30	87.6	84.6	92.3	92.6	103.7	110.5	Sunny
9:35	88.3	85.3	93.4	93.3	105.8	111.1	Sunny
9:40	88.2	85.6	93.1	91.9	106.3	111.1	Sunny
9:45	87.0	84.6	92.8	93.2	107.2	111.4	Sunny
9:50	88.3	84.8	92.3	90.5	104.1	111.2	Sunny
9:55	87.5	83.7	92.8	91.6	106.0	113.2	Partially Cloudy
10:00	91.0	85.7	93.8	93.4	107.5	116.2	Sunny
10:05	89.8	86.0	94.5	94.1	109.4	119.9	Sunny
10:10	90.1	86.2	95.7	93.3	110.1	121.5	Sunny
10:15	88.8	85.6	93.5	93.6	108.2	118.6	Sunny
10:20	89.8	86.3	96.1	93.4	109.8	122.9	Sunny
10:25	89.7	86.7	96.8	92.8	110.2	124.1	Sunny
10:30	88.2	85.8	96.5	91.5	108.0	122.1	Partially Cloudy
10:35	90.6	89.8	100.3	96.1	110.7	126.7	Sunny
10:40	86.7	85.9	96.8	91.0	109.5	125.3	Sunny
10:45	87.3	87.0	96.6	92.1	107.6	125.0	Sunny
10:50	88.4	87.7	96.8	93.4	108.8	126.4	Sunny
10:55	88.9	88.0	96.1	92.5	109.3	126.5	Sunny
11:00	88.5	87.5	96.6	92.9	109.0	125.9	Sunny

Table of results for morning measurements

White Plate - Midday Temperature Measurements

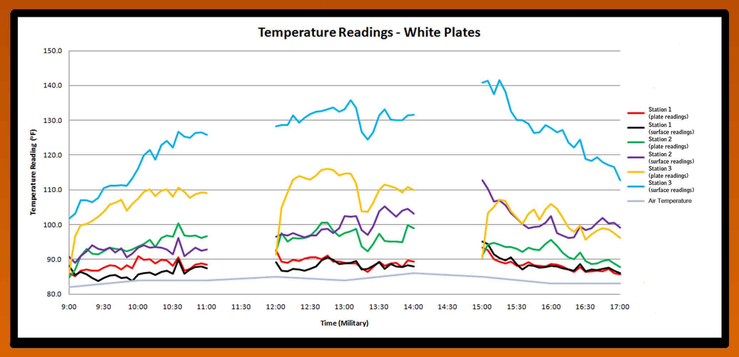
Time (military)	Temperature Readings (°F)						Weather Condition
	Station 1 (full shade)		Station 2 (filtering sunlight)		Station 3 (full sunlight)		
	Plate Reading	Surface Radiation	Plate Reading	Surface Radiation	Plate Reading	Surface Radiation	
12:00	92.6	89.2	92.4	96.5	91.5	128.2	---
12:05	89.3	86.8	97.5	97.2	104.8	128.7	Sunny
12:10	89.0	86.6	95.1	96.8	109.3	128.6	Sunny
12:15	89.8	87.3	96.1	97.6	113.0	131.5	Sunny
12:20	89.5	87.0	95.9	96.8	114.0	129.3	Sunny
12:25	90.3	86.8	96.1	96.3	113.4	130.7	Sunny
12:30	90.5	87.3	96.6	96.8	113.0	131.8	Sunny
12:35	90.6	88.0	98.5	96.9	114.1	132.5	Sunny
12:40	90.0	89.7	100.5	98.6	115.7	132.6	Sunny
12:45	91.1	90.6	100.5	98.8	116.1	133.2	Sunny
12:50	89.3	89.8	98.2	97.5	115.7	133.6	Sunny
12:55	89.3	88.6	96.7	99.0	114.2	132.5	Sunny
13:00	89.0	88.8	97.6	102.5	114.7	133.1	Sunny
13:05	88.8	89.0	98.1	102.3	114.6	135.7	Sunny
13:10	88.8	89.6	98.8	102.5	111.9	133.5	Mostly Sunny
13:15	87.4	87.1	93.7	98.5	103.8	126.7	Cloudy
13:20	86.4	87.3	92.3	97.1	103.7	124.4	Partially Cloudy
13:25	87.8	88.1	94.4	99.5	106.2	126.6	Partially Cloudy
13:30	89.4	89.1	97.4	103.8	110.0	131.4	Mostly Sunny
13:35	88.1	87.2	95.3	105.3	111.5	133.1	Sunny
13:40	88.8	88.6	95.2	103.6	111.0	130.2	Sunny
13:45	89.0	88.0	95.2	102.3	110.4	130.0	Sunny
13:50	87.8	87.8	95.0	104.0	109.3	130.1	Sunny
13:55	89.7	88.3	99.9	104.6	110.8	131.4	Sunny
14:00	89.4	88.0	99.0	103.1	109.9	131.6	Sunny

Table of results for midday measurements

White Plate - Afternoon Temperature Measurements

Time (military)	Temperature Readings (°F)						Weather Condition
	Station 1 (full shade)		Station 2 (filtering sunlight)		Station 3 (full sunlight)		
	Plate Reading	Surface Radiation	Plate Reading	Surface Radiation	Plate Reading	Surface Radiation	
15:00	93.3	95.2	91.1	112.8	90.4	140.8	---
15:05	92.7	94.4	94.3	110.3	103.3	141.4	Sunny
15:10	90.1	91.5	94.8	106.7	105.1	137.5	Sunny
15:15	89.3	90.4	94.2	106.9	107.1	141.6	Sunny
15:20	88.8	89.7	93.5	105.6	106.8	138.3	Sunny
15:25	89.3	90.5	93.5	103.4	103.8	132.6	Partially Cloudy
15:30	88.1	88.5	93.0	101.7	101.9	130.1	Partially Cloudy
15:35	88.3	87.1	92.2	100.1	100.2	130.0	Partially Cloudy
15:40	89.1	88.3	93.3	98.9	103.2	128.9	Sunny
15:45	88.3	88.1	92.8	99.3	104.4	126.4	Sunny
15:50	88.2	87.6	92.7	99.5	101.4	126.5	Partially Cloudy
15:55	87.9	87.7	94.4	100.5	104.3	128.7	Mostly Sunny
16:00	88.6	88.2	95.6	102.4	106.0	127.7	Sunny
16:05	88.5	87.9	93.9	97.6	104.5	126.5	Sunny
16:10	87.9	87.5	92.0	96.9	102.1	127.2	Sunny
16:15	87.0	87.0	90.6	96.1	99.2	123.5	Mostly Sunny
16:20	86.4	86.7	90.1	96.3	97.9	122.2	Mostly Sunny
16:25	87.8	88.6	91.9	99.4	99.6	124.5	Sunny
16:30	86.4	86.6	89.5	98.4	95.6	118.8	Cloudy
16:35	86.5	87.1	88.7	99.0	97.2	118.4	Partially Cloudy
16:40	86.7	86.9	88.8	100.6	98.2	119.3	Sunny
16:45	86.5	87.3	89.6	101.9	98.9	117.9	Sunny
16:50	87.3	87.6	89.9	100.3	98.6	117.1	Partially Cloudy
16:55	86.1	86.8	88.8	100.5	97.6	116.5	Sunny
17:00	85.7	86.0	87.7	99.1	96.1	112.7	Sunny

Table of results for afternoon measurements



Graph presents the variations in temperature readings at the distinct measurement periods of the day.

Preliminary Analysis and Recommendations:

-Station 3's observed behavior is an increase from the morning hours to a steady peak behaviour mid day and a steady decline in the afteroon. Station 2 had behavior similar to station 3 except not as intense. Station 1 showed a consistant behavior during all three periods with barely any increase.

-Direct contrast between station 1 and stations 2 and 3 indicate that the element of shade has a strong influence over the temperature perceived in the area.

-Process needs to be repeated using the black plates to be able to better compare surface radiation measurements to solar radiation measurements.

-Air temperature was underneath all station measurements which indicates thermal radiation has a larger impact over thermal comfort concerns.

List of Images:

1-Site Location Map
2-Site Location Key Map
3-Station 1 (upward view)
4-Station 1 (plate location)
5-Station 2 (upward view)
6-Station 2 (plate location)
7-Station 3 (upward view)
8-Station 3 (plate location)

Future Plans:

-Conduct same test using black plates.
-Measure temperature due to vehicles using infrared thermometer.
-Determine relationship between measurements and pedestrian activity.

References:

-Chávez del Valle, Francisco J. "Zona Variable de Comfort." Thesis. Universidad Politécnica de Cataluña, 2002. Print.
-Ochoa de la Torre, J. "La Vegetación como instrumento para el control microclimático" Thesis. Universitat Politecnica de Catalunya. 1999. Print