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Bright is the new black—multi-year performance of high-albedo roofs in an urban climate

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Outline

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- Conclusion
- My experimental scheme

Introduction

- Non-vegetated surfaces with lighter surfaces replace anthropogenic dark will be relatively uncontroversial. Candidates here include surfaces at grade ,such as road pavements and sidewalks, building facades and rooftops.

- Maximizing rooftop albedo, or alternatively using cool colors, is now recognized as preferred to conventional dark membranes.

- The two broad categories of flat roof membranes are (i)single-ply and (ii) multi-ply asphaltic systems (modified bitumen, mod-bit, and built-up roofing (BUR))

- There are fewer academic studies of single-ply membranes and that our study is distinguished from prior research by comparing these two broad categories of white roofs . Moreover our study is the first for white roofing performance in New York City.

Introduction

- Report on and evaluate small-scale performance data from three monitored white roof projects in New York City.

Table 1. Location, membrane specifications and installation costs per square foot (/sq. ft) for test sites.

Location	Membrane type	Product/manufacturer	Installation cost[a] ($/sq. ft)	Initial solar reflectance[b]	Age (yrs)
MoMA Queens	Asphaltic membrane painted with elastomeric acrylic	APOC® 247 sun-shield white reflective roof coating	$0.50[c] (+ cost of underlying membrane)	0.87	2
Con Edison	EPDM rubber membrane	Carlisle sure-white FleeceBACK	$15–18[c] $25–28[d]	0.76	3
Queens Botanical Garden	TPO membrane	Carlisle sure-weld TPO membrane	$15–18[c] $25–28[d]	0.79	4

[a] Costs include materials and labor; material costs are roughly 15% of the total installation cost.
[b] Using test method ASTM C-1549. Cool Roof Rating Council (CRRC).
[c] Non-union labor.
[d] Union labor.

Project site descriptions（MOMA）

Figure 1. White elastomeric acrylic paint surface, black asphaltic control membrane and instrumentation at the MoMA Queens test site (Long Island City, New York, NY). The surrounding gray area is the aged white roof that had darkened significantly in the two years before the sensor deployment began.

Results（MOMA）

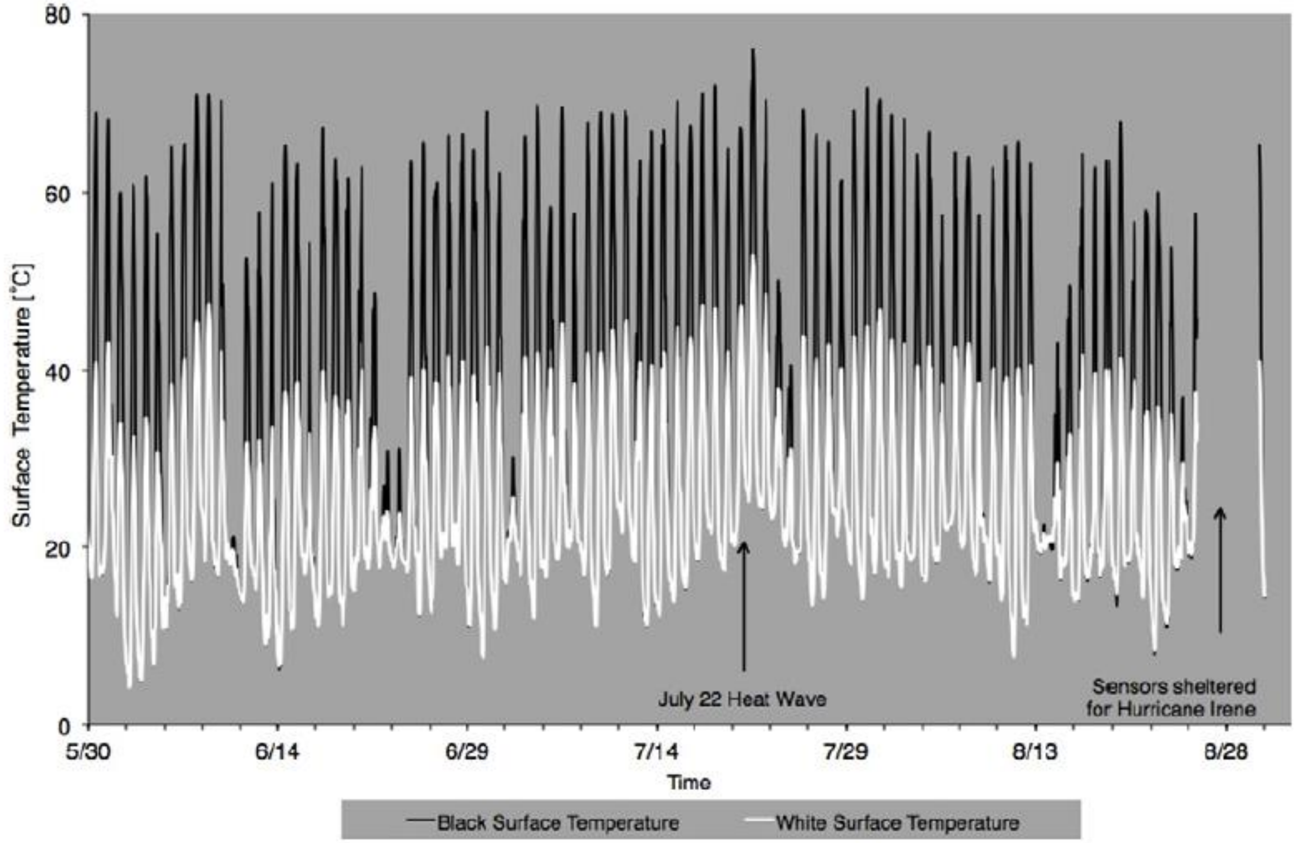


Figure 2. Comparative white and black roof temperatures at the MoMA Queens site, where white acrylic paint was applied to a black asphaltic substrate. Data are shown for the meteorological summer June–August 2011.

Project site descriptions（MOMA）

Figure 3. White roof conditions during the summers of 2010 and 2011 showing albedo loss effects over time. The original black membrane was first coated in summer 2009. (a) Surface conditions one year later after a fresh test patch was applied in summer 2010. (b) Surface conditions two years later just before sensor deployment began. (c) Surface conditions at the start of data collection after a second recoating.

Results（MOMA）

Table 2. Average (Avg) peak and average daily temperature differences observed on the MoMA Queens site for the two test surfaces during the summer 2011 (left) and peak temperatures, difference and average daily difference for the hottest day of that summer (right).

MoMA Queens summer 2011	(°C)	MoMA Queens 22 July 2011—heat wave[a]	(°C)
Avg peak black (B) temp	63.3	Peak black temp	76.5
Avg peak white (W) temp	39.7	Peak white temp	53.1
Avg B and W peak temp diff	23.6	Peak temp diff	23.4
Avg B and W daily temp diff	6.6	Avg B and W daily temp diff	8.6

[a] All-time NYC electric load record.

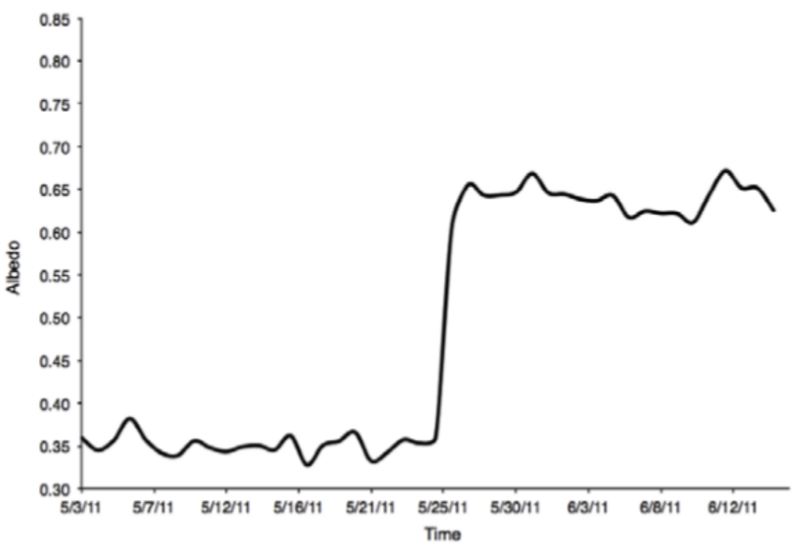


Figure 4. Observed albedo data for the MoMA Queens site before (at two years of age) and after a fresh acrylic paint recoating, which took place on 25 May 2011.

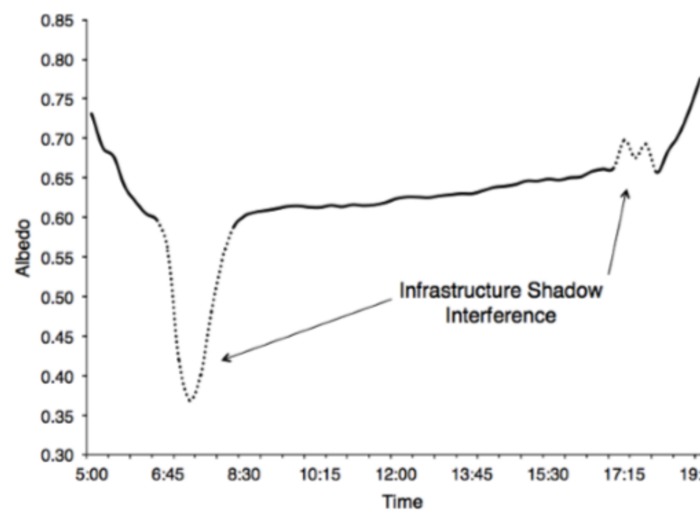


Figure 5. Hourly averaged albedo data for the MoMA Queens site during the summer of 2011 showing the change during the daily solar cycle. Dashed lines indicate interference by rooftop infrastructure, which cast shadows on the sensors during sunrise and sunset.

Results（MOMA）

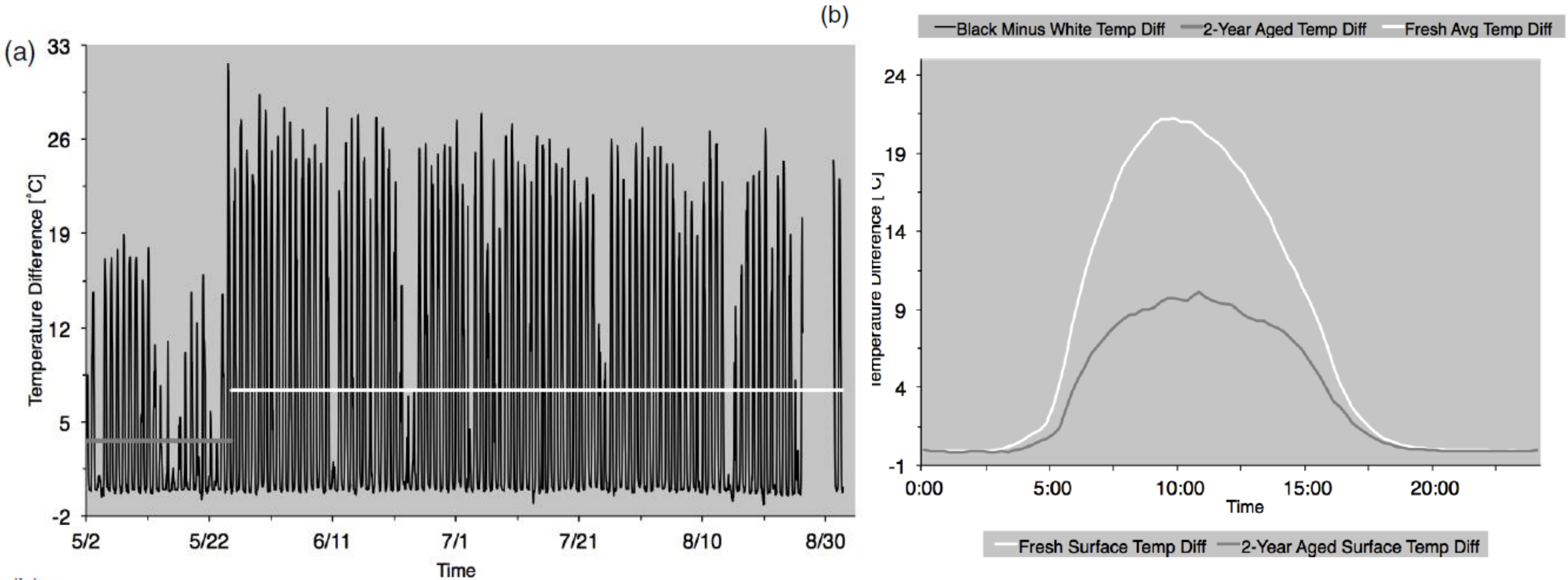


Figure 6. (a) Hourly black minus white temperature differences measured over summer 2011 at the MoMA Queens site. Also shown are the average pre-recoating difference value (horizontal gray line) and post-recoating difference value (horizontal white line). (b) Black minus white surface temperature differences averaged over the diurnal cycle for the fresh coating (white line) and also for the two-year aged surface (gray line) at the MoMA Queens site. The aged surface lost approximately half its temperature control, consistent with an approximately 50% albedo loss.

Results （MOMA）

$$\varepsilon_{\text{actual}} = 0.95\left(\frac{T_{\text{IR}}}{T_{\text{actual}}}\right)^4$$

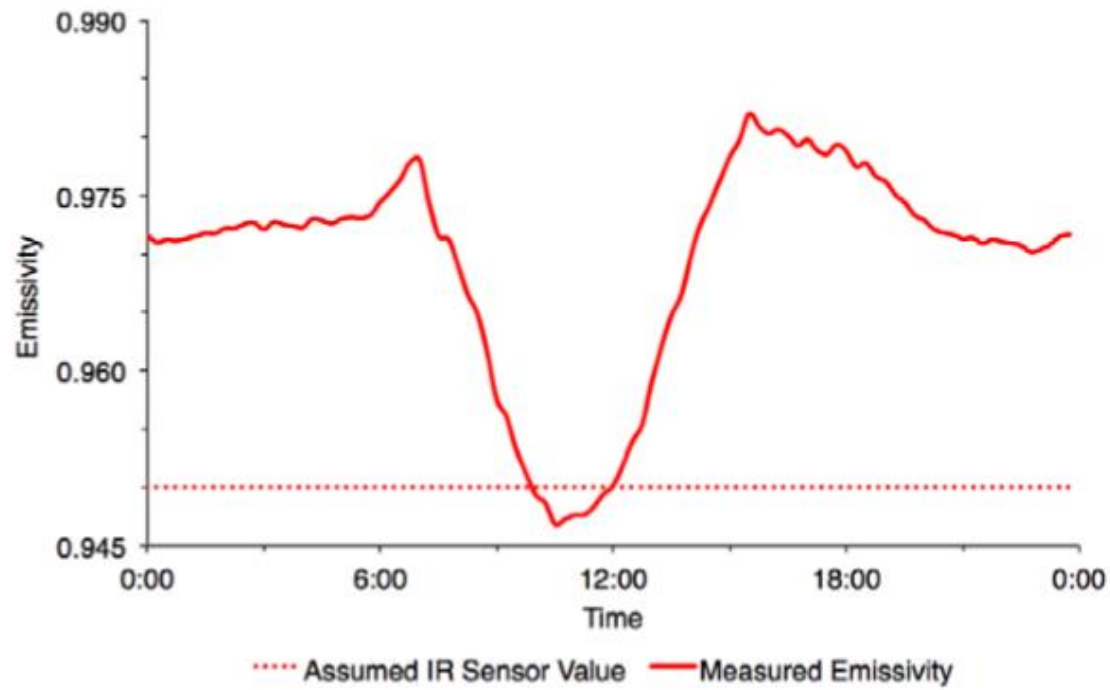


Figure 7. Average hourly emissivity values at the MoMA Queens site, calculated using data for equation (1), over the diurnal cycle are shown by the upper fluctuating line. The constant dashed line is the assumed infrared sensor emissivity of 0.95 that was programmed into the datalogger.

Project site descriptions（CELC）

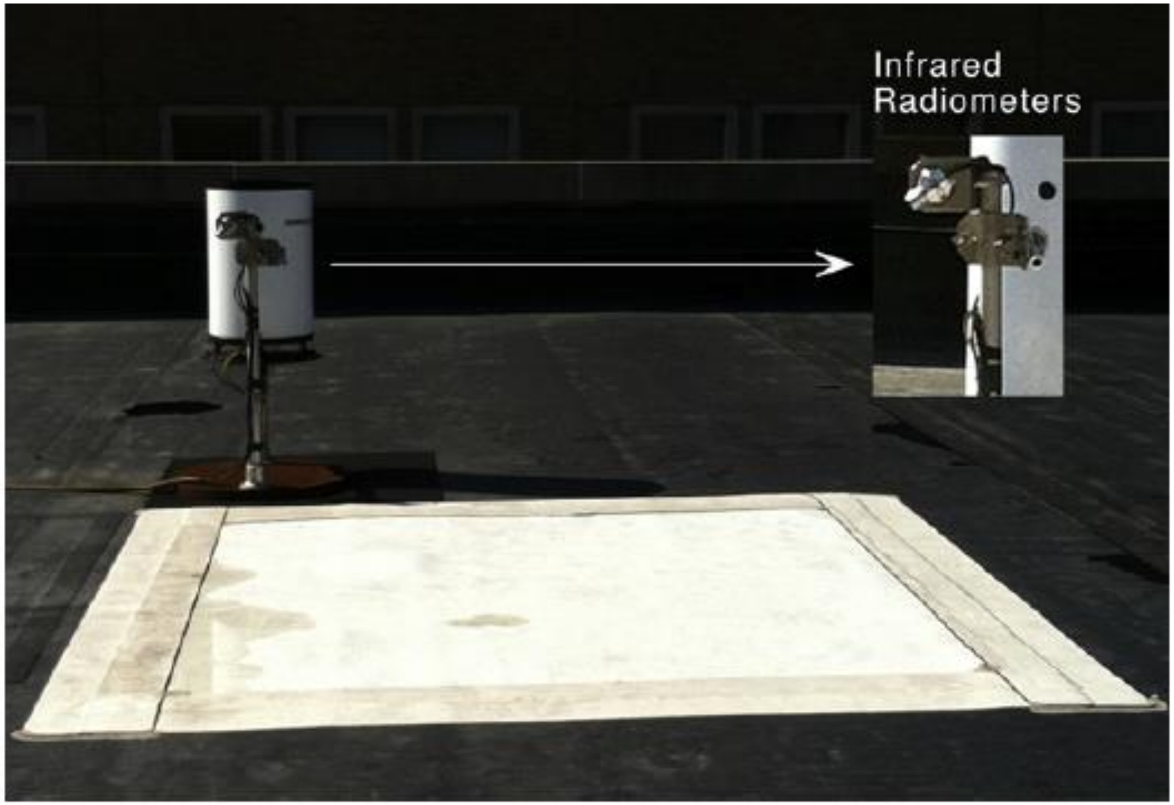


Figure 8. Black and white EPDM membranes and surface IR temperature sensors (the white bucket in the background is a rain gauge) at the Con Edison study site. The membranes are three years old at the time of this photograph and the white membrane has not been cleaned during that time

Results（CELC）

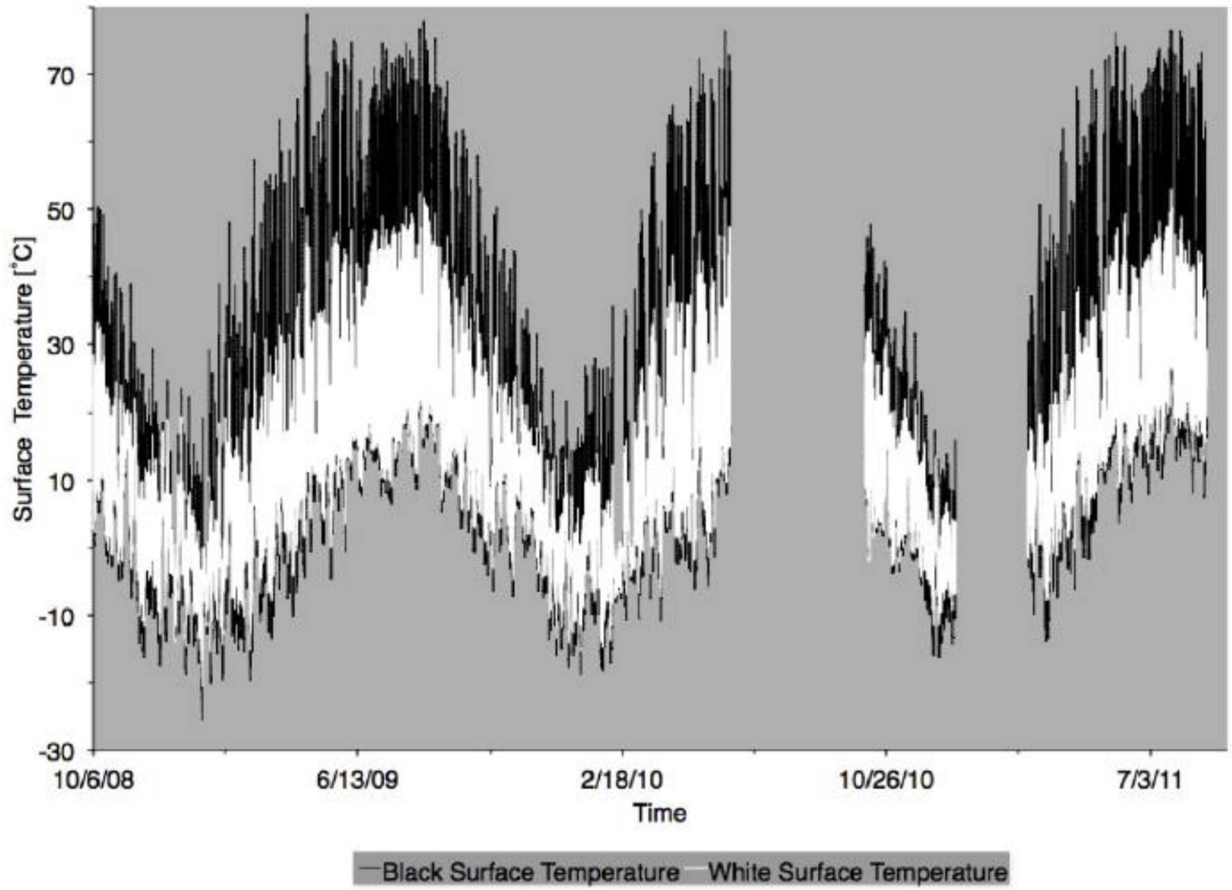


Figure 9. Nearly three years of average hourly black and white membrane temperatures observed for the black and white EPDM single-ply membranes at the Con Edison site (October 2008–August 2011).

Results（CELC）

Table 3. Summary of average (Avg) peak and average daily temperature differences observed on the Con Edison Learning Center for the two test surfaces for meteorological summer 2011 (left) and peak temperatures, difference and average daily difference for the hottest day of that summer (right).

Summer 2011	(°C)	22 July 2011—heat wave[a]	(°C)
Avg peak black (B) temp	65.4	Peak black temp	77.4
Avg peak white (W) temp	41.7	Peak white temp	53.4
Avg B and W peak temp diff	23.7	Peak temp diff	24.0
Avg B and W daily temp diff	5.1	Avg B and W temp diff	6.7

[a] All-time NYC electric load record.

Project site descriptions（QBG）

Figure 10. Sensor and test surfaces set up ((a) and (b)) on the Queens Botanical Garden. The building TPO membrane is actually a sloped canopy (c) requiring the use of a small horizontal test membrane.

Results（QBG）

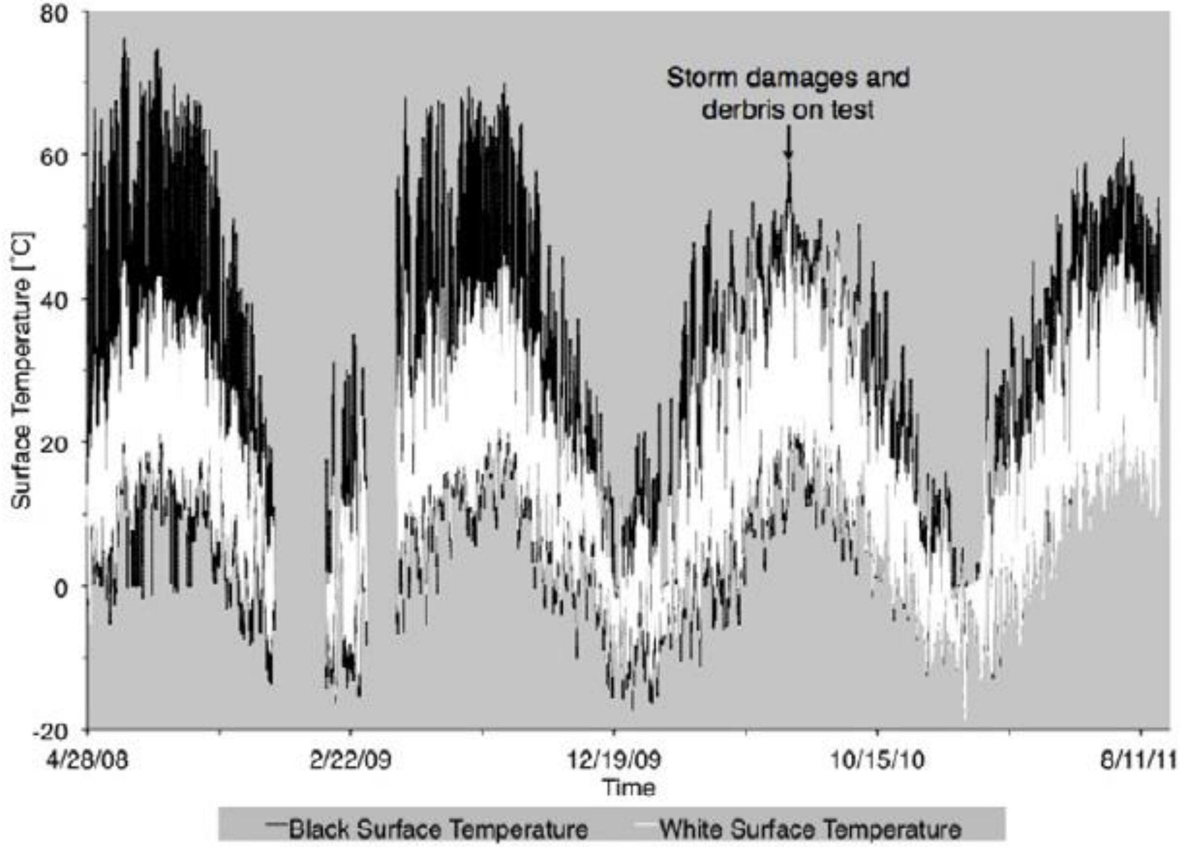


Figure 11. Hourly black and white membrane temperatures at the Queens Botanical Garden site (2008–2011). The test site roof experienced severe storm weather damage during the summer 2010.

Results（QBG）

Table 4. Summary of average (Avg) peak and average daily temperature differences observed on the Queens Botanical Garden site for the two test surfaces for meteorological summer 2011 (left) and peak temperatures, difference and average daily difference for the hottest day of that summer (right).

Summer 2011	(°C)	22 July 2011—heat wave[a]	(°C)
Avg peak black (B) temp	51.0	Peak black temp	64.0
Avg peak white (W) temp	39.4	Peak white temp	53.1
Avg B and W peak temp diff	11.6	Peak temp diff	10.9
Avg B and W daily temp diff	3.3	Avg B and W daily temp diff	3.7

[a] All-time NYC electric load record.

Results

Table 5. Average (Avg) black and white temperature values and average difference for the three test sites over summer 2011.

Site White membrane type	MoMA Queens Fresh acrylic paint	Con Ed Three-year old EPDM	QBG Four-year old TPO
Avg black temp (°C)	31.8	31.5	Na[a]
Avg white temp (°C)	24.4	26.4	25.1
Avg temp diff (°C)	7.3	5.1	Na[a]

[a] Black geotextile cloth not comparable to waterproof membranes.

Conclusion

- The professionally installed white membranes are maintaining their temperature control effectively and are meeting the Energy Star Cool Roofing performance standards requiring a three-year aged albedo above 0.50.

- The EPDM membrane shows evidence of low emissivity; however this had the interesting effect of avoiding any ‘winter heat penalty’ for this building.

- The painted asphaltic surface shows high emissivity but lost about half of its initial albedo within two years of installation.

- The acrylic approach is such an important ‘do-it-yourself’, low-cost, retrofit technique, offers the most rapid technique for increasing urban albedo.

My experimental scheme

Background and Significance :

- China has and will be undergoing large scale urban sprawl from now to 2050 so it is of great importance now to evaluate its environmental effect and study the mitigation measures before it reaches climax. This can enlighten an effective way of sustainable development for urban environment.

- The use of materials presenting high reflectivity to the solar radiation and high spectral emissivity, cool materials, contribute to increasing the urban albedo and it is considered to be one of the more promising and powerful techniques to mitigate the heat island phenomenon (Akbari et al., 2009).

- China's urban roof material is mainly composed of cement and concrete,they have low albedo. We suppose to choose three kinds of common cool materials to test their ability to mitigate the urban heat island phenomenon.

Research Design:

- Time

The initial time is in June to August, December to next February.

- Location

Wende building's roof in Nanjing University of Information Science and Technology.(fig.1)

Figure1. Experimental Distribution of the Roof of the North Area of Wende building

- The number of people

Four people are required temporarily, including the person installing the instrument.

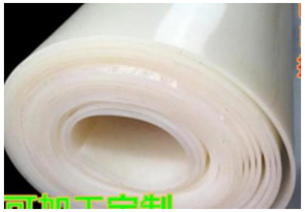
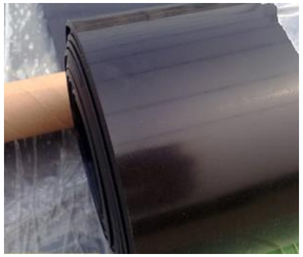
- Instrument design

Table1. The equipment we need

Equipment name	Number	Model	Picture	Price(RMB)
CNR4 Net Radiometer Pt-100 temperature sensor and heater	3 （we’ve got 2）	CNR4		59,475
Apogee20 Infrared Radiometer	6 (we’ve got 9)	T109		6,838
109-L temperature probe(-50℃ to 70℃)	3 or 6 (None yet)	SI-111		2,760

- Experimental Sample design

Table2. The samples we choose

Material name	Required Quantity	Picture	Price(RMB)
White acrylic paint	4kg		59/kg
White EPDM rubber membrane	24 ㎡		TBA
Black EPDM rubber membrane	8 ㎡		24/㎡
Asphaltic membrane coated with aluminum foil	60 ㎡		11/㎡

- Experimental Procedure Design

Figure2.Test area 1(acrylic)

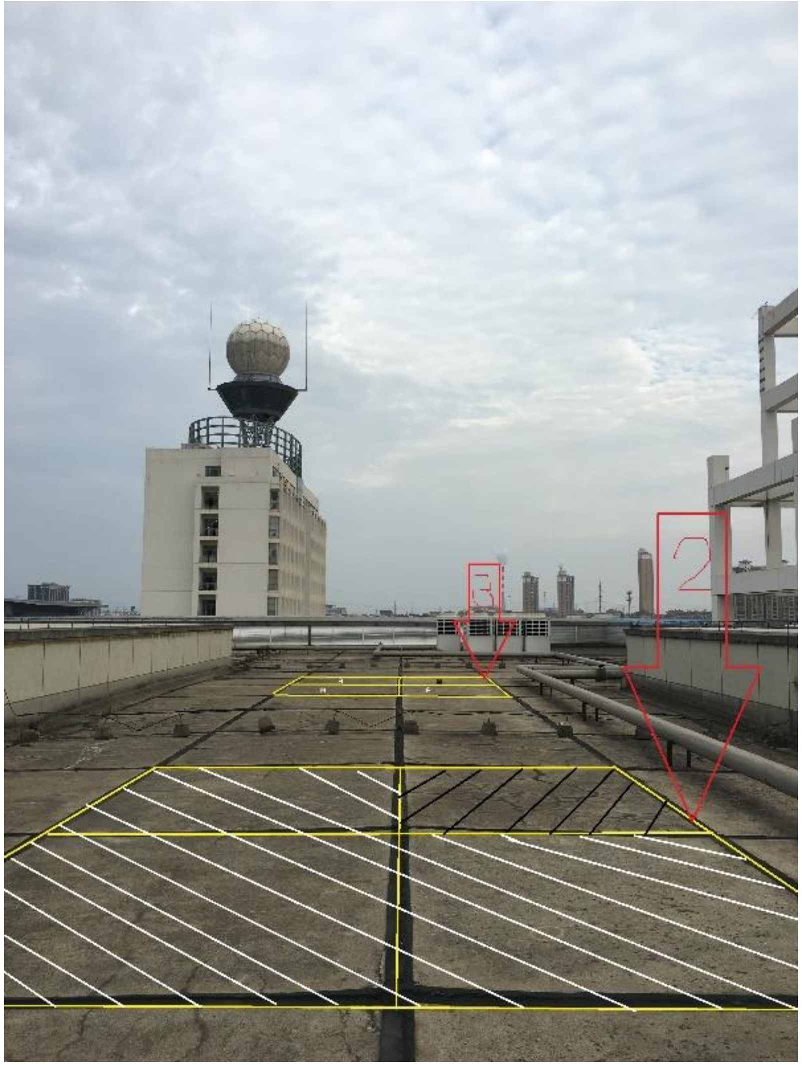


Figure3.Test area 2（EPDM）

Figure4.Test area 3（aluminum foil）

Figure4.Landscape of Test area 2、3

Thank you！