

# Sunlight Degradation of Polymeric Materials used in Transportation Infrastructures

Siavash Vahidi  
Drexel University

10/19/2016



DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

*College of Engineering*

# Introduction



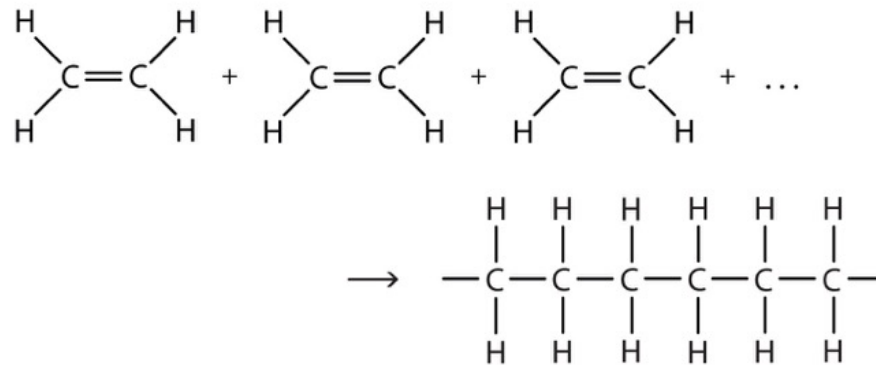
DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

*College of Engineering*

## Polymers / Properties:

- Polymers are substances composed of a large number of repeating units resulting in large molecules that give polymers their specific properties.



- Being used increasingly in civil engineering applications.
  - Mechanical properties
  - Chemical Properties
  - Economical Materials



# Applications:



- Polymer Modified Asphalt
- FRP
- ADA Mats
- Polymer Pipes
- Marine Structures
- Roof Coating
- Slope erosion control



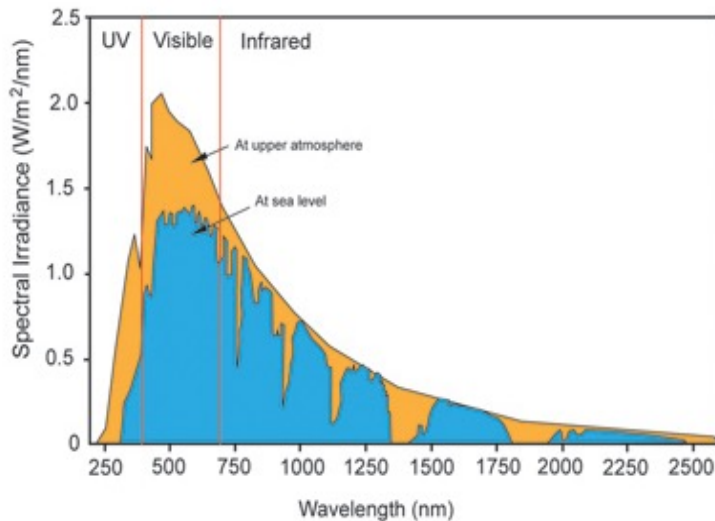
DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering

# Sunlight Radiation:

- Expected to have a service life of at least a few decades.
- Many applications require the polymer to be exposed to the sunlight.
- Long-term performance against sunlight should be studied.
- A combination of electromagnetic waves with different wavelengths.



$$E = h\nu = h \frac{c}{\lambda}$$

Where;

$E$  = Radiation energy

$h$  = Planck's constant ( $6.62607004 \times 10^{-34} \text{ J.s}$ )

$\nu$  = Frequency

$\lambda$  = Wavelength

$c$  = Velocity of light in a vacuum ( $3 \times 10^8 \text{ m.s}^{-1}$ )

Planck–Einstein Equation

Ultraviolet (UV) : 295 nm- 385 nm

Visible Light: 385 nm- 700 nm

Infrared (IR): > 700 nm

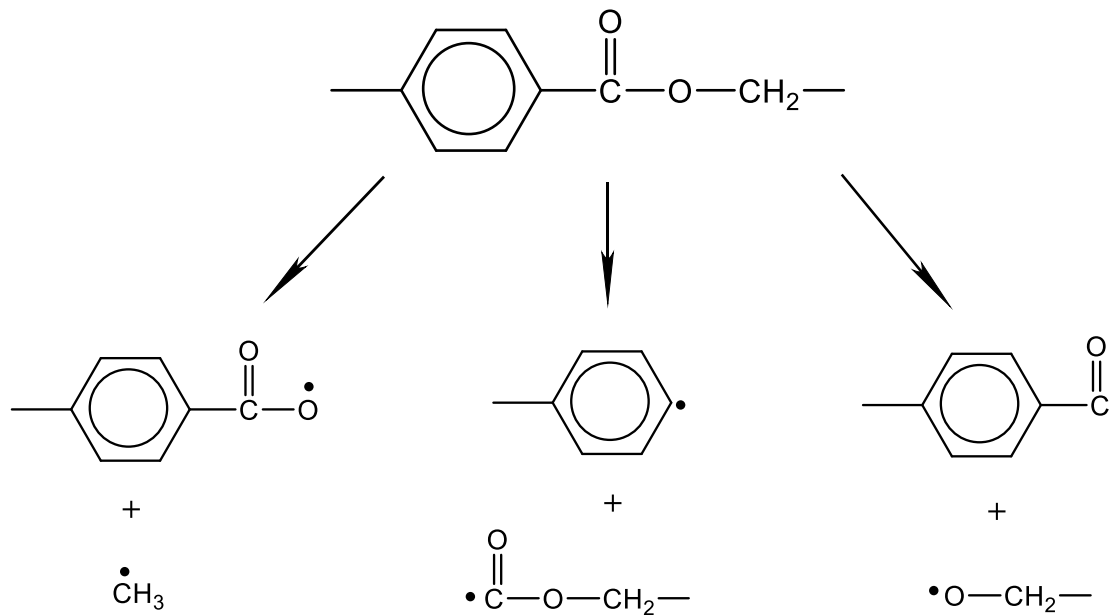


DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering  
College of Engineering

# Sunlight Induced Degradation:

## ➤ Chain scission



Chain scission around the ester group in Polyester

## ➤ De-crosslinking



DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering

# Exposure Methods



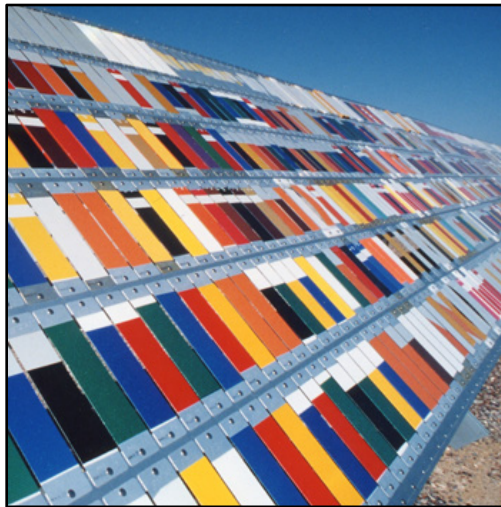
DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

*College of Engineering*

## Outdoor Exposure:

- Most realistic results
- Time consuming
- ASTM D5970
  - 45° Angle
  - Facing South



DREXEL UNIVERSITY

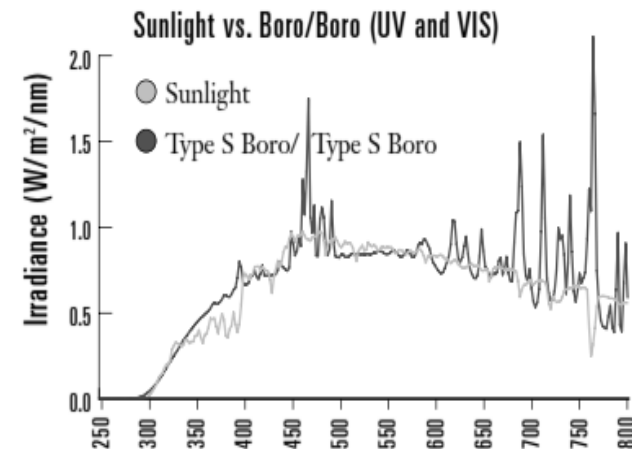
Civil, Architectural, and  
Environmental Engineering

College of Engineering



# Laboratory Exposure (Weatherometer):

- Accelerated degradation
- Controlled environment
- Xenon lamp
- Inner/Outer filters
- Capable of simulating the natural sunlight radiation more closely than other artificial light sources.



DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering

# Degradation Parameters

## (Drexel Experiments)



DREXEL UNIVERSITY

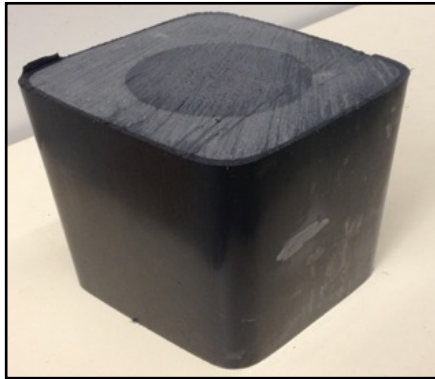
Civil, Architectural, and  
Environmental Engineering

*College of Engineering*

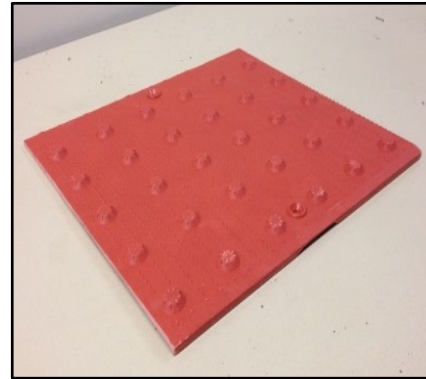
# Drexel Experiments:

## ➤ Materials:

Structural HDPE



ADA Mats (Polyester, Polyurethane, Epoxy)



- Exposure: Test coupons are placed in an Atlas Xenon Weatherometer (Ci-4000) and are exposed to different levels of irradiation, temperature, and relative humidity.



DREXEL UNIVERSITY

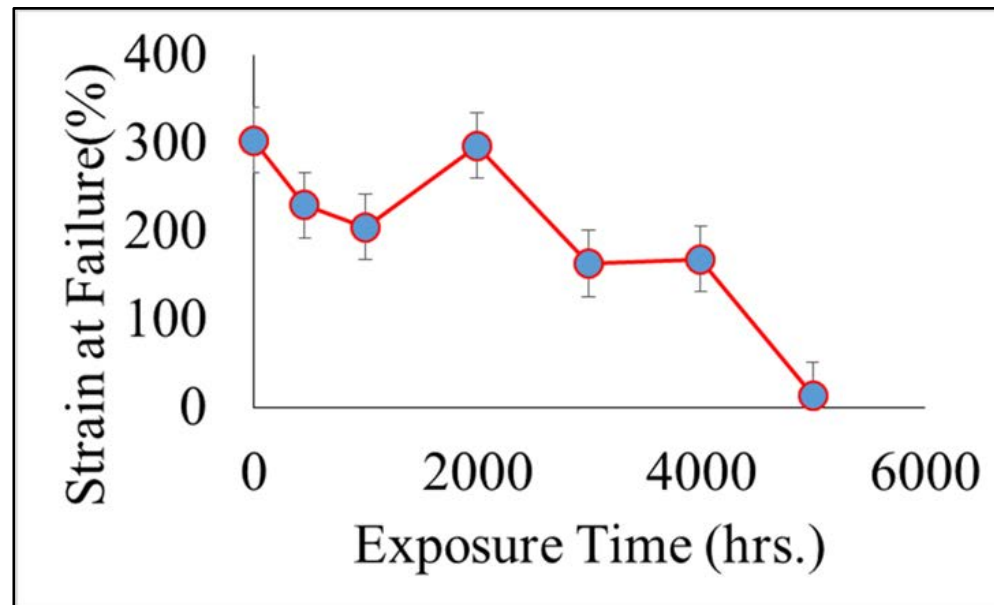
Civil, Architectural, and  
Environmental Engineering

College of Engineering

## Degradation Parameters (HDPE):

### ➤ Tensile Test:

The tensile properties were used to assess the mechanical properties of the HDPE material.



**4500 hr**



**5000 hr**



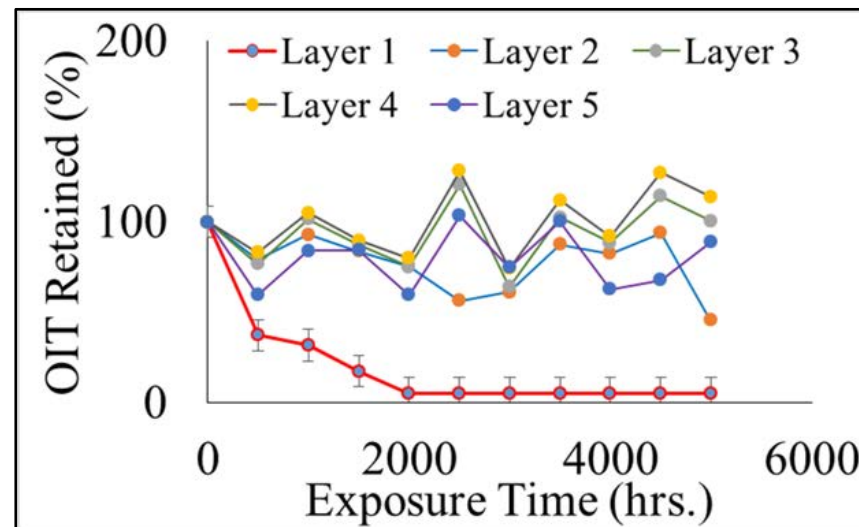
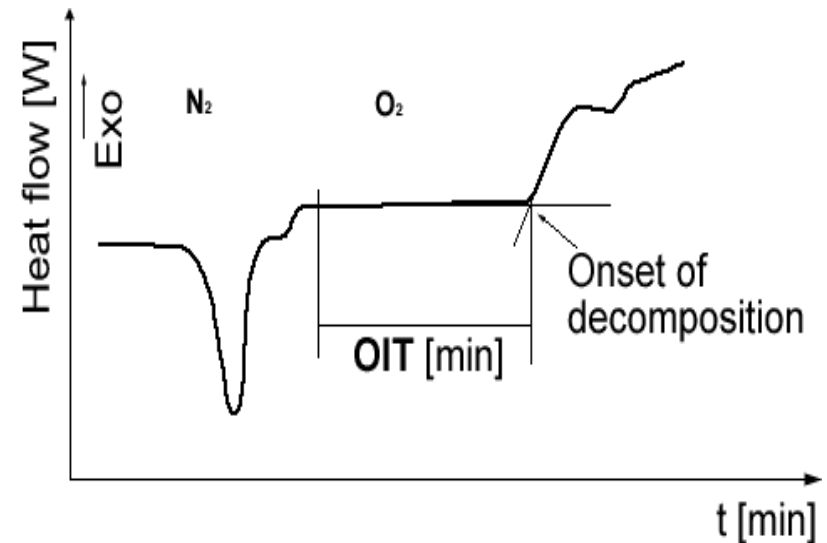
DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering

## Degradation Parameters (HDPE):

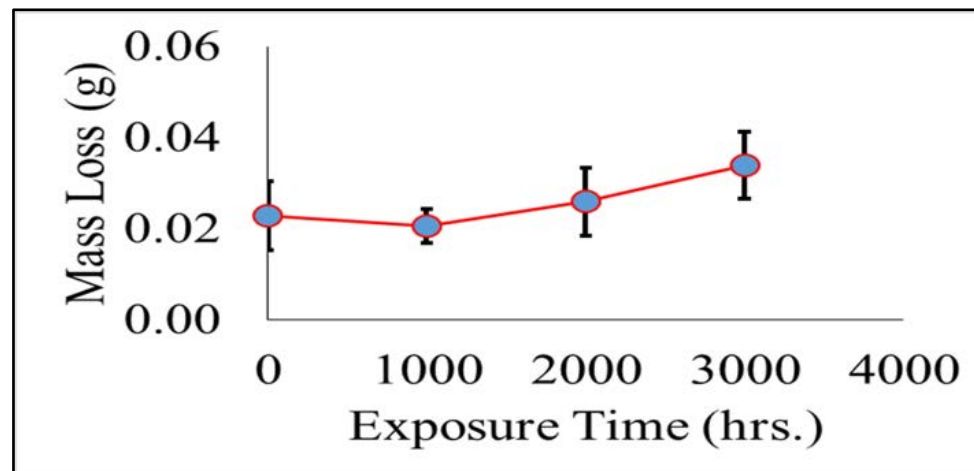
- Oxidative Induction Time (OIT): Chemical degradation was monitored by OIT test.
- Samples are heated up under a nitrogen atmosphere to 200°C. Oxygen is then introduced and the length of time from the onset of degradation is measured.



## Degradation Parameters (ADA Mat):

### ➤ Abrasion Test:

Mechanical degradation was measured by an abrasion test device made at Drexel university.



DREXEL UNIVERSITY

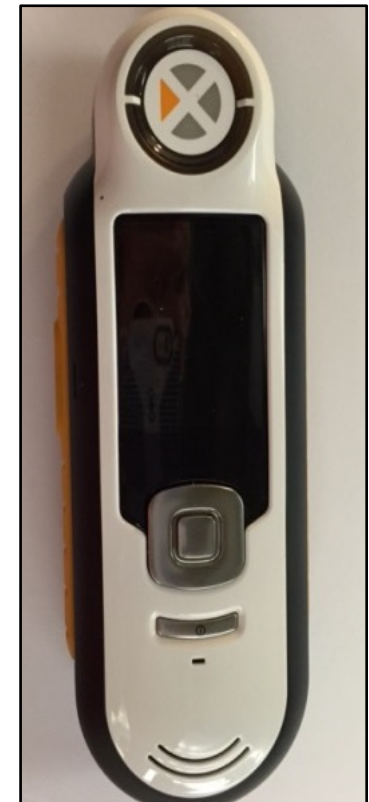
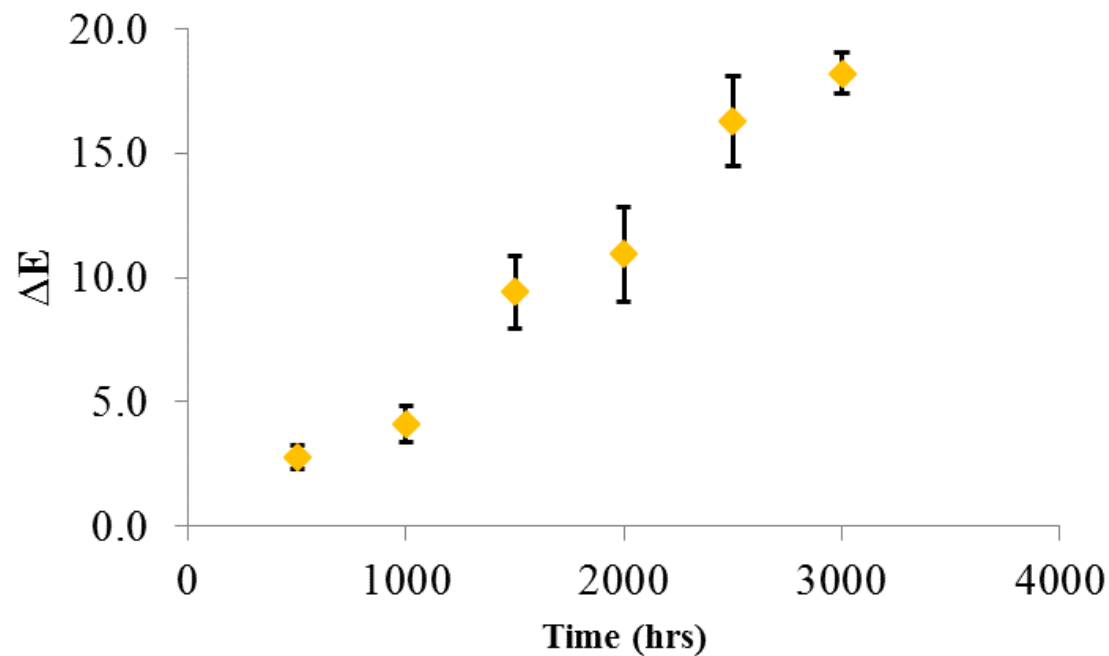
Civil, Architectural, and  
Environmental Engineering

College of Engineering

## Degradation Parameters (ADA Mat):

### ➤ Color Change:

The color of the ADA coupons was measured using a spectrophotometer (X-rite RM200QC). The color difference,  $\Delta E$  value, was measured for each coupon.



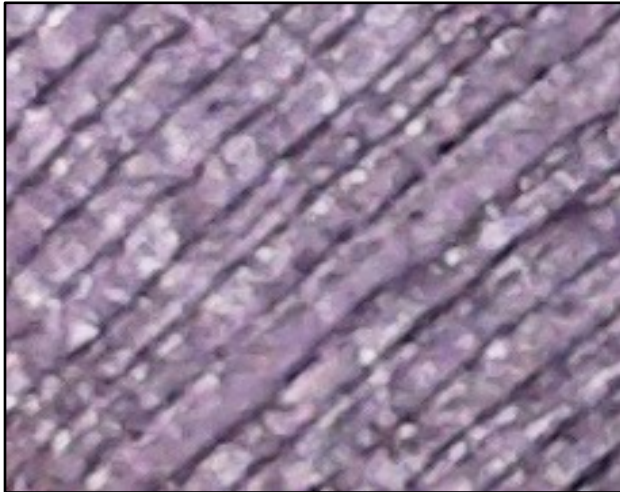
DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering



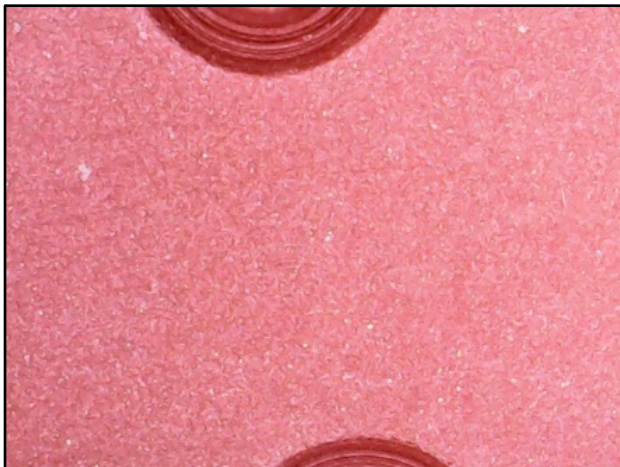
# Surface Morphology:



0 Hours



5000 Hours



0 Hours



3000 Hours



DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering



## Outdoor Exposure:

Test coupons are also exposed to the natural outdoor environment (ASTM D5970) in Gainesville, FL by our colleagues at the University of Northern Florida (UNF) and will be sent back to Drexel for further testing for correlation purposes.

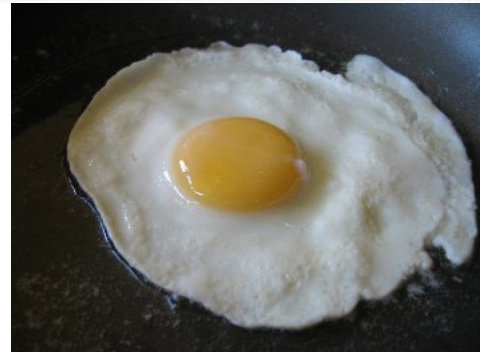
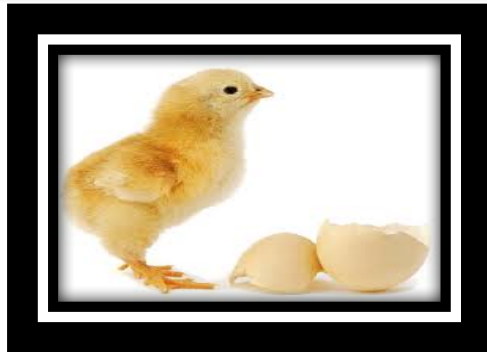


DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering

## Correlation Methods:



### Parameters to be considered:

- Higher irradiance levels are used to accelerate the degradation. It can result in unnatural chemical degradation.
- Cage effect.
- Different regions of the light spectrum have different degradation efficiency on different polymers.
- UV stabilizers (change response to UV region)
- Polymer color (change response to visible region)



DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

College of Engineering

**Thank you for your attention!**

**Questions or Comments?**



DREXEL UNIVERSITY

Civil, Architectural, and  
Environmental Engineering

*College of Engineering*