Class 5: Aging of FRP Composites

http://www.uic.edu/depts/cme/research/ssndtl/activities/images/image1004.jpg

PRIME Modules
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Aging is change to the material structure over time

Aging: In metals and ceramics, this is the process of precipitating a supersaturated solid solution (precipitation hardening).

In polymers, this is the process of degradation of properties over time.

The main sources of degradation are exposure to UV light and absorption of moisture.

The polymer structure changes over time which affects the properties of the FRP

Matrix Phase: Degradation of the polymer decreases the mechanical properties of the matrix, especially lowering the transverse loading capabilities of the composite

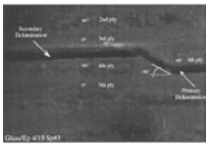
Fiber Phase: Aging of fibers results in a loss of tensile load capacity with polymeric fibers, strain hardening of metal fibers.

Interface Region: Over time debonding between fiber and matrix phases occurs, loss of reinforcement leads to catastrophic failure.

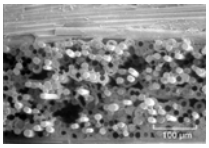
Aging influences interface properties to result in failure of the FRP

Over time, the effects of aging result in debonding/ delamination (gaps in the interface between the fiber and the matrix form)

Also, the fibers can be pulled out of the composite



Debonding/Delamination
http://www.cerc.gatech.edu/



Fiber Pullout from Matrix
http://www.lerc.nasa.gov/Other_Groups/RT1997/5000/5130hurst.htm

The FRP patch can also debond from the concrete structure

Changes over time at the FRP/ Concrete interface can result in debonding of the patch from the civil infrastructure

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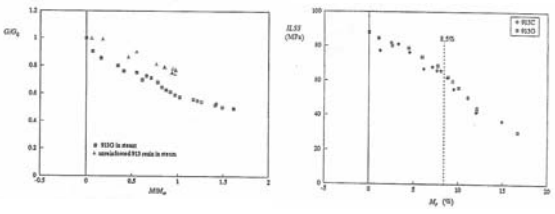
Water absorbed into the polymer degrades the mechanical properties

Humidity introduces water into the matrix/interface which decreases the shear modulus.



Left: Percent change of shear modulus with percent change in weight due to moisture
Right: ILSS (interlaminar shear strength vs percent moisture content.

R.D. Adams, M.M. Singh, "The Dynamic Properties of Fibre-Reinforced Polymers Exposed to Hot, Wet Conditions" , *Composites Science and Technology*, **56**, 977 (1996)

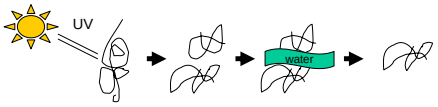
UV exposure lowers the MW, lowering the mechanical properties of the polymer

UV exposure can modify the matrix though the process of chain scission, the breaking of chains into segments.

This lowers the MW of the chains, lowering the TS of the matrix.

It also makes the diffusion of water into the polymer much faster.

The combination of 1000 hours of UV and humidity exposure will produce approximately a 29% drop in matrix strength.

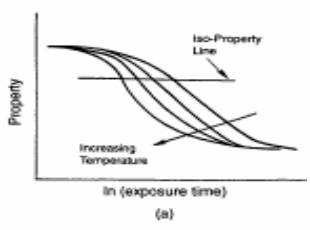


B. Kumar, R. Singh, T. Nakamura, "Degradation of Carbon Fiber-reinforced Epoxy Composites by Ultraviolet Radiation and Condensation."

Temperature accelerates the aging process

Temperature can affect aging time.

Iso-Property – a constant value of a given property at any time/temperature combination.

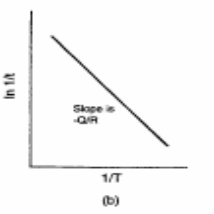


Increasing the temperature increases the moisture absorption

We are going to see next class that moisture absorption (diffusion of water) increases with either temperature or time.

Let the moisture absorption be your Iso-property and plot ln (1/t) vs 1/T.

So by increasing the temperature we increase diffusion and thus decrease aging time. This is known as accelerated aging.



In summary, a polymer degrades over time which can result in the failure of the FRP

Aging of the polymer is the change in the material's structure over time.

Aging can result in decreased mechanical properties of the polymer matrix and fiber and interface failures between the fiber/matrix and the FRP patch/concrete structure

Aging results from exposure to moisture and UV light.

Aging is accelerated at higher temperatures due to the faster diffusion of the moisture and the change in the polymer matrix at the glass transition temperature.

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