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The Performance Requirements for Recycled HDPE Materials in Various Pipe Applications

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Recycling of Bottles Tops 2.8 Billion Pounds in 2017

American Chemistry Council (Nov 17)

- 29% Decrease from 2016
- 1.04 Million Pounds of HDPE
  - HDPE Corrugated Pipe Utilizes Approximately 75% of this Material

Material Properties

ASTM Cell Class 424420C

• Density	**0.947-0.955 g/cm^3**
• Melt Index	**1.0 – 0.4**
• Flexural Modulus	**80,000-110,000 psi**
• Tensile Strength at Yield	**3,000-3,500 psi**
• Environmental Stress Crack Resistance	**ESCR or NCLS**
• Hydrostatic Design Basis at 23^{0}C	**0**
• Color and UV Stabilizer	**C**

Issues with Recycled Plastics for Pipe

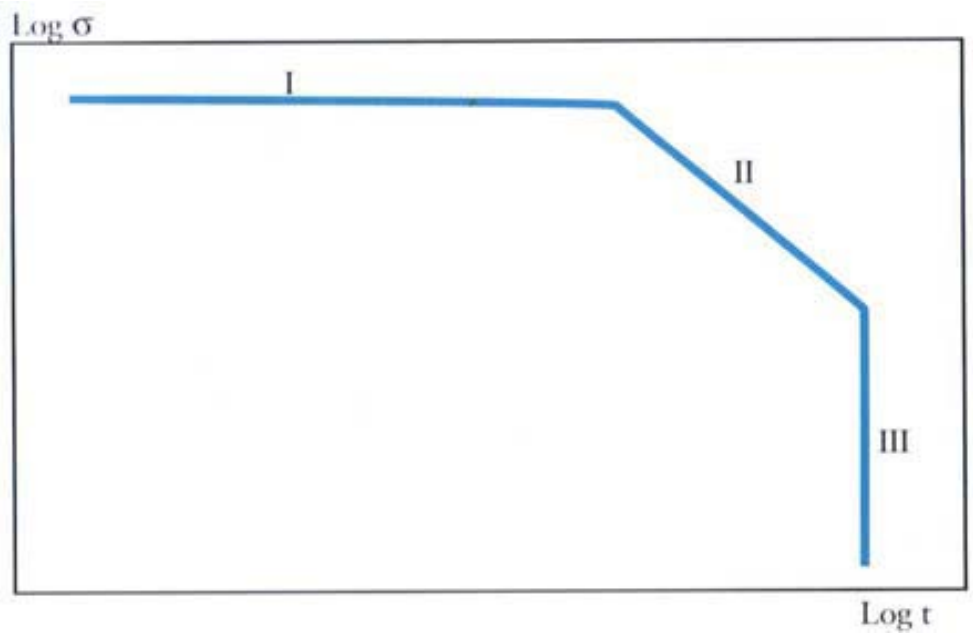
- *Contaminants*
- *Stress Crack Resistance*
- *Long-Term Mechanical Properties*
  - *Project Service Life*

Long-Term Mechanical Properties

- *ASTM D2990 (50-year properties)*
  - *Tensile Strength 900 psi*
  - *Modulus of Elasticity 22,000 psi*

Design Criteria

- *Stage I: Ductile*
- *Stage II: Brittle - Stress Crack Resistance*
- *Stage III: Chemical Degradation*



Stage III Oxidation

- *NCHRP Report 696*
  - *Thermal Stability*
  - *Oxidative Induction Time*

Main Assessment Requirement for Recycled HDPE Pipe

- *Stress Crack Resistance*
  - *ASTM F2136*
    - *(NCLS Test Method to Determine Slow Crack Growth Resistance of HDPE Resins or HDPE Corrugated Pipe)*
  - *ASTM F3181*
    - *(UCLS Test Method for The Un-notched, Constant Ligament Stress Crack Test for HDPE Materials Containing Post-Consumer Recycled HDPE)*
  - *Test Specimens*
    - *Resin Plaques*
    - *Extruded Pipe Plaques*
    - *Pipe Liner Samples*

Main Assessment Requirement for Recycled HDPE Pipe

- *Stress Crack Resistance*
  - *Virgin Resins (with Contaminants)*
  - *Recycled Materials*

Corrugated HDPE NCLS Applied Stress

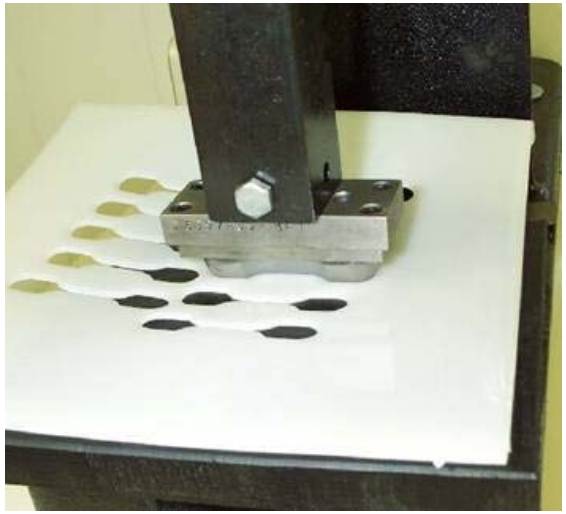
- *AASHTO LRFD Bridge Design Specifications*
  - *300 psi Maximum Stress Based on 20,000 psi $E_{50\text{-}100}$*
    - *50-100 year Service Life*
  - *1.5 Load Factor*
    - *450 psi Applied Stress*
      - *Rounded up to 500 psi*
  - *5% Vertical Deflection*
    - *1.5% Strain Limit (2.25% Factored Strain Limit)*
      - *6.15% AASHTO Factored Stain Limit*

NCHRP Report 429

- *Existing 24-hr Resin ESCR (Environmental Stress Crack Resistance)*
  - *Not Adequate*
- *Required Minimum 14-hr NCTL (Notched Constant Tensile Load)*
- *Recommended 24-hr NCTL on Virgin Resin*

NCHRP Report 631

- *Required Minimum 33-hr NCLS (Notched Constant Ligament Stress)*
  - *Virgin Resin*
- *Required Minimum 24-hr NCLS*
  - *Replaqued Sample from Extruded Pipe*
- *Required Minimum 18-hr NCLS*
  - *Sample Directly from the Pipe Liner*

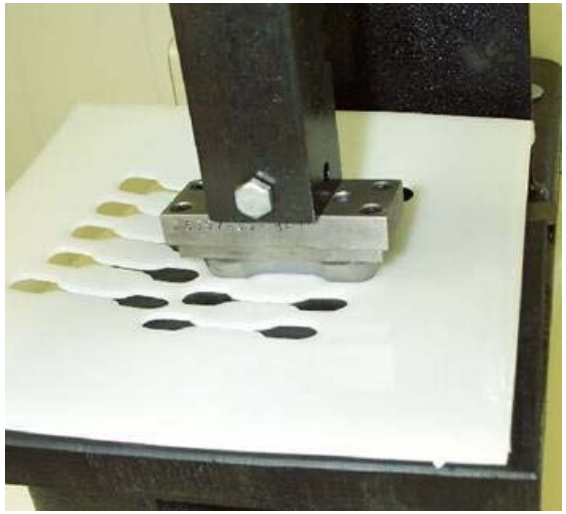


Sensitivity of NCLS Evaluation

- *Notching Procedure*
- *Crack Depth*
- *Blunt Edge Cuts*
- *Laboratory Procedures*
- *Variability of Results*
  - *Virgin vs Recycled*
- *Thin Sample Cross-Section*

NCHRP Report 870

- ***Required Minimum 34-hr UCLS*** *(Un-Notched Constant Ligament Stress)*
  - *100-year Service Life*
  - *23°C Temperature*
  - *Tensile Design Stress of 500 psi*



Stress Crack Requirements for Pipe with Virgin/Recycled Materials

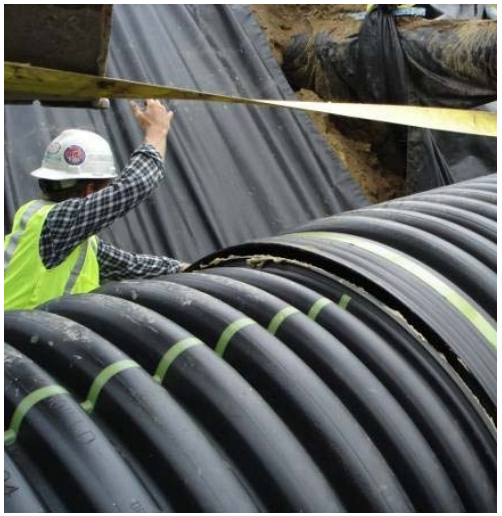
- *Agricultural Drainage Pipe (ASTM F667)*
  - *24 hr ESCR & Proposed 6 hr UCLS*
- *Storm Drainage (ASTM F2648)*
  - *12 hr NCLS & Proposed 12 hr UCLS*
- *Highway Culverts & Municipal Storm Sewers (AASHT0 M294 & ASTM F2306)*
  - *24 hr NCLS & 34 hr UCLS*
- *Sanitary Sewers (ASTM F2947)*
  - *41 hr NCLS & Proposed 48 hr UCLS*

Closing Comments

- *Mechanical Properties of Recycled and Virgin HDPE Pipe are Essentially the Same*
- *Oxidation and Thermal Stability are not an Issue with Recycled HDPE Pipe*

Closing Comments

- *Stage II Stress-Crack Resistance Requirements for HDPE Pipe are Very Conservative*
- *NCLS Values for Virgin & Recycled HDPE Pipe Should be Identical*
- *UCLS Values Access Contaminants More Accurately than NCLS Test*



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Questions