NI ST Measurement Science and Standards Development

Aaron Forster

Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD
NIST Mission

To promote U.S. innovation and industrial competitiveness by advancing
- measurement science,
- standards, and
- technology

to enhance economic security and improve our quality of life
The NIST Laboratories

NIST’s work enables

- Science
- Technology innovation
- Trade
- Public benefit

NIST works with

- Industry
- Academia
- Other agencies
- Government agencies
- Measurement laboratories
- Standards organizations

Manufacturing, materials, fire, construction, building environment, earthquake...

Computing, mathematics, statistics...

Polymers, ceramics, analytical, surface chemistry, biotechnology, chemistry, thermodynamic...

Electron, quantum, radiation, time, weight, optics, electronics, nano...

For materials, polymers, biology, chemistry, physics; 28 exp. stations
# Materials and Structural Systems Research Division

## Jon Martin, Chief

### Polymeric Materials

**Joannie Chin**

- Nanoparticle Release During Life Cycle of Nanostructured Polymeric Materials
- Photoreactivity of Narrow Band Gap Metal Oxide Nanostructures
- Service Life Prediction for Pipe Materials and Building Sealants
- Service Life Prediction of Photovoltaic Packaging Materials
- Surface and Interface Characterization of Polymers

### Structures

**Fahim Sadek**

- Fire Resistance Design and Rehabilitation of Structures
- Prevention of Disproportionate Structural Collapse
- Wind Engineering and Multi-Hazard Failure Analysis

### Inorganic Materials

**Ken Snyder**

- Doubling Concrete Service Life
- Quantitative Characterization of Concrete-Making Materials for Performance Prediction and Increased Fly Ash Utilization in Concrete
- Rheology-Based Processing of Concrete

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http://www.nist.gov/el/building_materials/index.cfm
Service Life Prediction of Polymers

Outdoor Weathering

- Slow
- Non-repeatable

Laboratory Accelerated Weathering

- Same Degradation Mechanism?
- Chemical
- Physical
- Mechanical
- Metrology
- Methodology
- Models

- Shorten time-to-market of new polymer products for industry
- Establish warranty periods
- Minimize product risk and liability

2m Integrating Sphere
Service Life Prediction – Unfilled Epoxy Coating

Successfully linked field and laboratory exposures for an unfilled model epoxy

Oxidation (1725, 1658 cm⁻¹)

Law of Reciprocity is obeyed

Linkage of outdoor and laboratory data sets
Technology Development and NIST

Discovery / Proof of Principle
- Peer-reviewed journal articles
- Intellectual property, SBIR
- Contact: NIST PIs

Cooperation / Consortia
- Alliance for Regenerative Medicine
- IBBR with Univ. of Maryland
- Contact: NIST Laboratories

Rapid growth of an industry
- Industry-wide standard practices
- Transition to manufacturing
- Contact: NIST Programs

Mature industry
- Greater focus on efficiency
- Integrated network of stakeholders
- Contact: All of the above

- World-class measurements
- World-class science
- High impact publications
- Nobel laureates, National Academy

- Multidisciplinary programs
- Alignment with roadmaps
- Technology Innovation Program
- Cooperative Agreements

- Lead standards development
- Measurement solutions; Tech transfer
- Material Measurement Lab

- Standards and standard practices
- Calibrations services
- ISO / ASTM
- Manufacturing Extension Partnership

Workshops and Working Groups
Interaction with Hydrogen Industry: Hydrogen Pipelines

• Who
  • NIST workshop representing pipeline owners, industry and standards organizations, academic researchers, national laboratories, and government agencies

• Topics
  • Materials
  • Test Techniques and methods
  • Codes, Standards, and Safety

• Non-metallic Characterization:
  • Permeation for different pipe material classes
  • Joint Performance: \textit{joint geometry, bonding, mechanical fastening}
  • Composition: FRP vs. Plastic materials
  • Design: \textit{bending strengths and pressure capability}
  • Long-term Performance: \textit{degradation factors and fatigue performance specifications}


www.nist.gov: NISTIR 6649

Many of these factors remain unknown
Interaction with Nuclear Industry:
NESCC

• **Who**
  - The Nuclear Energy Standards Coordination Collaborative (NESCC) is a cross-stakeholder forum to identify and respond to the current needs of the nuclear industry.
  - NESCC is open to all stakeholders, government legislative and regulatory bodies, industry, standards developing organizations, certification organizations, and other interested parties.

• **Task Groups**
  - Assemble users, technical experts, utilities, SDO representatives, and regulators
  - Survey standards and regulatory documents
  - Identify standards gaps, needs, and timeline to fill gaps
  - Produce a report:

  **NESCC Polymer Pipe Task Group (PPTG)**
  *Polymer Pipe Codes and Standards for Nuclear Power Plants*
## Task Group Membership

<table>
<thead>
<tr>
<th>Name</th>
<th>Last</th>
<th>First</th>
<th>Title</th>
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<tr>
<td>1</td>
<td>August</td>
<td>James</td>
<td>VP Technical Operations</td>
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<td>2</td>
<td>Thompson</td>
<td>David</td>
<td>Technical Director</td>
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<td>3</td>
<td>Boros</td>
<td>Stephen</td>
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<td>Plastics Pipe Institute</td>
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<td>4</td>
<td>Clark</td>
<td>Mark</td>
<td></td>
<td>Nibco</td>
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<td>Rowley</td>
<td>Wes</td>
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<td>Focht</td>
<td>Eric</td>
<td></td>
<td>US Nuclear Regulatory Commission Office of Nuclear Regulatory Research</td>
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<td>7</td>
<td>Forster</td>
<td>Aaron</td>
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<td>Mason</td>
<td>Jim</td>
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<td>Mason Materials Development, LLC</td>
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<td>Golliet</td>
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<td>12</td>
<td>Lever</td>
<td>Ernest</td>
<td>Senior Institute Engineer</td>
<td>Gas Technology Institute</td>
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<td>15</td>
<td>Schaaf</td>
<td>Frank</td>
<td>Consultant</td>
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<td>Svetlik</td>
<td>Harvey</td>
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<td>Independent Pipe Products, Inc.</td>
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<td>17</td>
<td>Wheeler</td>
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<td>Andrew</td>
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<td>Jimmy</td>
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<td>The Dow Chemical Company</td>
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<td>Zimmerman</td>
<td>David</td>
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</table>
focus on HDPE standards; can't do it all:

**PPI: TR-5 ~ 40 pages**
**ASTM I: 87**
**DVS: 23**
**DIN (German): 31**
**ISO: 85 reference**
**EN:52**
**BS EN ISO 150**

Consolidated list of gaps

Code case approach to address standards gaps
NIST and the Gas Technology Institute have developed a collaboration that will develop industrially relevant measurements and standards to comprehensively solve the industry and regulatory challenges for wide adoption of HDPE.

**NIST**
- Tool set to measure intrinsic properties of HDPE pipe and fusion joints
- Linkage of microstructure to performance
- Feasibility and limits for accelerated joint standards
- Critical measurements to develop a fatigue standard for service life prediction

**Gas Technology Institute (GTI)**
- SCG test methods for bi-axial stress states
- Critical Flaw Size: Database of realistic flaws, constitutive equations, and shift factors for bimodal pipe materials
- Fusion Optimization
- Simulations and fatigue test methods for life prediction

*AWWA HDPE SLP report*
Measurement Challenges

Examples

Chemistry and Environments Interact
Tunnel Accident

Boston, Massachusetts: July 10, 2006

Big Dig Project

Ted Williams Tunnel

D Street Portal

I-90 Connector Tunnel

Source: Mass. State Police
Ceiling Details

- NTSB – contracted with Turner-Fairbank Highway Research Center (FHWA) for long term creep tests
  - Time consuming so limited number or tests

- Background studies: Creep and factors that control creep
  - Use time-temperature superposition to predict creep

<table>
<thead>
<tr>
<th>Test</th>
<th>$T_g$ or $T_E$</th>
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<tr>
<td>Epoxy A</td>
<td>48.3±1.3</td>
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<tr>
<td>Epoxy B</td>
<td>50.3±1.5</td>
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Predictions for Creep Compliance

- Because of uncertainty due to deviations from thermo-rheologically simple behavior and transformation – small differences not significant.

- Differences are not small
- Epoxy A is significantly more susceptible to creep than Epoxy B.
- Epoxy A is predicted to have significant creep in short time
- Why when other properties are so similar?
- Is this prediction real?
Results from FHWA

- 2000 lb tests - below design load
  - Similar elastic response
  - Major difference in creep behavior
- 4000 lb tests - above design load but below allowable load
  - Similar elastic response
  - Major difference in creep behavior
  - Failure in less than 80 days
- Consistent with our predictions
  - Superposition approach can strongly indicate trends
- Epoxy A used in D-street Portal
  - Not bad adhesive, but poor choice with sustained loads

from FHWA
Failure Modes Depend on Environment

Behavior controlled by:
- Load only at high loads,
- Independent of amount of water in composite
- Time exposed to load & water

Applied Stress

Fatigue Life (cycles)

Load

Time

Measurement Science For Composite Pipes

Multiple time and length scales of interest for large diameter, high pressure pipe:

• Short term:
  – *Identification and control of essential variables for processing, fusion/joining, installation*
  – Early identification and measurement of factors responsible for performance
  – Effect of microstructure and failure process – *processing and developing standardized material property measurements*

• Long term:
  – *Standards to address durability and damage tolerance key to safe operation*
  – Understand interactions between *temperature, wear, UV, fatigue, creep/stress relaxation, aging, mechanical stress, aggressive chemicals*
    • Develop well-defined accelerated tests that reflect use conditions and failure modes
  – *Identification of condition monitoring and probabilistic models to support intelligent asset management*
  – Facilitate decision strategies for repair and replacement
  – Effect of microstructure/heterogeneity/interface on *crack growth rate*

➤ Microscale Measurements:
  • Correlate performance to specific *microstructure*
  • *Extend* this understanding to bulk performance and models
Improving Standards for Composite Pipe

Life Management Program Elements

- Piping System Design
- Demonstration of Structural Integrity
- Degradation Evaluation and Modeling
- Repair Technologies
- Leak Detection & Operational Controls
- In-Service Inspection Program
- Codes & Standards Application
- H2 Piping Systems Service History Evaluation

Amato, Overview of ASME Hydrogen Codes and Standards Development, 5th Annual H2 Codes and Standards Conference, Detroit, MI (2010)
Questions?

References:


4. Amato, Overview of ASME Hydrogen Codes and Standards Development, 5th Annual H₂ Codes and Standards Conference, Detroit, MI (2010)
