Pavement Marking Durability

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Research Overview and Objectives

- Longitudinal pavement markings are the most widely implemented traffic control devices.
- Numerous types of materials are applied to roadways including thermoplastic, epoxy, and polyurea.
- Degradation is caused by environmental factors.
- Goals:
  - To determine service life and overall cost of various markings in terms of degradation with consideration to durability, retroreflectivity, and cost.
  - To develop recommendations for a pavement marking application and replacement strategy.
Background

- Pavement markings provide a visual reference that aid to position the car within the roadway.
- MUTCD 3A.02 – markings that must be visible at night, should be retroreflective unless ambient lighting assures that markings are adequately visible and consideration should be given to selecting pavement marking materials...
- Retroreflective materials are utilized during application to provide for nighttime visibility.
Background, Cont.

- “Retroreflectivity is the property to reflect light back towards its source.” - FHWA
- Spherical glass beads are embedded into the marking binder during installation.
- The binder contains pigments which scatter the light and allow more for light reflection.
Over time, pavement markings degrade and become less reflective.

Causes of degradation include:
- Improper application.
- Wear by vehicles.
- Oxidation and ultraviolet sunlight.
- Fading pigments.
- Binder can become brittle creating holidays or bead release.
- Damage from winter maintenance practices.

Once markings no longer exhibit acceptable nighttime visibility, the markings should be replaced.
Project Scope

- **Phase I: Literature Review.**
- **Phase II: Data compilation from existing projects.**
- **Phase III: Data Collection from new projects.**
- **Phase IV: Data Reduction/Interim Report**
- **Phase V: Economic Analysis of life cycle costs.**
- **Phase VI: An evaluation of the deterioration mechanisms of the performance factors.**
- **Phase VII: Final Report.**
Phase I: Literature Review

- To gain knowledge of testing procedures, current research, current operation practices and innovative technologies regarding pavement markings.
  - Field Studies.
  - Laboratory Studies.
  - Sampling Procedures.
  - Pavement Management Marking Systems (PMMS).
Data Collection (Phase II and III)

- Marking Type:
  - Thermoplastic (76%)
  - Polyurea (20%)
  - Epoxy (4%)
  - Waterborne Paint
  - Permanent Tape

- Site Location Selection:
  - Roadway Classification
  - Geographic Location
  - AADT
  - Age
Data Collection (Phase II and III)

- Thermoplastic Markings (AASHTO M-249):
  - Homogenously composed of pigment, filler, resins (hydrocarbon or alkyd) and glass reflectorizing spheres.
  - Thermoplastic resin – linear macromolecular structure that will repeatedly soften when heated and harden when cooled.
    - Hydrocarbon – petroleum derived resins (most frequently specified).
    - Alkyd – naturally occurring resin that is resistant to petroleum products.
  - Subject to VTrans Standard Specifications 646.07(c) and 708.08.
Data Collection (Phase II and III)

- Polyurea Markings:
  - Two part component, polyurea coating material with glass beads and possibly additional reflective elements.
  - Chemical technology based on two component reacted materials:
    - Amine blend
    - Isocyanate mixture
    - Results in very rapid reactions which produce extended chain polymer structures generally in membranous form.
  - Subject to VTrans Specifications 646.07(modified) and 708.15.
Data Collection (Phase II and III)

- Epoxy Markings:
  - Two component (two parts resin to one part curing agent), epoxy materials with glass beads applied as it cures
  - Epoxy resin – polyether resin formed originally by the polymerization of bisphenol A and epichlorohydrin, having high strength and low shrinkage during curing.
  - Subject to VTrans Specifications 646.07(b) and 708.08(c).
Data Collection (Phase II and III)

- **Glass Beads:**
  - Since 1997, crushed clear glass (max. size of 33 mils) has been added to thermoplastics at a rate of 9-10% of the total weight.
  - Remainder comprised of 35% filler materials, 25% binder material, and 30% glass beads.
  - Glass beads slightly smaller gradation than AASHTO Specification M 247-05 (Type I).
Data Collection (Phase II and III)

- Test Sites:
  - A minimum of 5 randomly selected sites as delineated by mile marker location.
  - Within each test site – 5 locations are assessed at intervals of 10’ and includes: edge, center or skip lines.
  - Many sites were established at locations with markings up to two years old.
  - Evaluation criteria includes the following –
    - Retroreflectivity (ASTM E1710-97 modified)
    - Durability (ASTM D913-00)
    - Photographic Representation
Data Collection (Phase II and III)

- Retroreflectivity readings were collected with LTL 2000 Retrometer
  - 30-meter geometry or “driver geometry” - (Adopted by ASTM)
  - millicandelas/m²/lux
  - Calibration
  - Provides for reproducibility, accuracy, and repeatability
  - Winter Data Collection
Data Collection (Phase II and III)

- When possible, initial retroreflectivity readings were collected within 14 days of application in order to comply with ASTM Standard D 6359-99.

  - Minimum retroreflectance requirements:
    - White – 250 mcdl
    - Yellow – 175 mcdl
Phase IV: Data Reduction

- All raw field data was recorded.
- Data was transcribed into Excel spreadsheets.
- Data was processed to find anomalous readings.
- Plots of Retroreflectivity reading vs. time:
  - Readings displayed significant variability.
  - All markings displayed similar patterns.
Phase IV: Data Reduction

Cavendish/Weathersfield (VT 131 WB)
Thermoplastic Markings

Retroreflectivity (mcdl)

Date

White Edge Line
Yellow Center Line
Phase IV: Data Reduction

Brookfield/Montpelier (I-89 NB) White Edge Line
Varied Thickness of Thermoplastic

Retroreflectivity (mcd/l)

Date

05/24/2002 12/10/2002 06/28/2003 01/14/2004 08/01/2004 02/17/2005 09/05/2005

125 mil
90 mil
Phase IV: Data Reduction

Burlington/S. Burlington (I-189) White Edge Line
3M LPM Series 1200

Retroreflectivity (mcd/ft)

Date

06/28/03 10/26/03 02/23/04 06/22/04 10/20/04 02/17/05 06/17/05
Phase IV: Data Reduction

Lyndon/Sheffield (I-91 NB)
Epoplex LS50

Retroreflectivity (mcd/l)

Date

White Line
Skip Line
Yellow Line
Phase IV: Data Reduction

- **Estimate for Service Life – Statistical Modeling of the degradation of retroreflectivity:**
  - Roadway Characteristics
  - Traffic Characteristics
  - Other Attributes

- **Evaluation Considerations:**
  - Large Variability
  - Need for pre-defined benchmark
## Phase IV: Data Reduction

### Recommended Retroreflectivity Values

<table>
<thead>
<tr>
<th>1998 FHWA Research-Recommended Pavement Marking Values</th>
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<tbody>
<tr>
<td><strong>Type</strong></td>
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<tr>
<td>-----------</td>
</tr>
<tr>
<td><strong>Option 1</strong></td>
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<tr>
<td><strong>Option 2</strong></td>
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<td><strong>Option 3</strong></td>
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<tr>
<td><strong>White</strong></td>
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<tr>
<td><strong>Yellow</strong></td>
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</tbody>
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Phase IV: Data Reduction

- Thermoplastic Markings:
  - Degradation analysis in terms of retroreflectivity, time since installation, and cumulative traffic passages.
  - 19 Roadway Sections.
  - 1,100 Individual Measurements.
  - 69 Longitudinal Lines.
  - Grouped by roadway, material, and color.
Phase IV: Data Reduction

White Edge Line Retroreflectivity

Non-Freeway White Line Thermoplastic Pavement Markings

average retroreflectivity = -56.802Ln(# of cumulative vehicle passes in '000) + 556.66
R^2 = 0.6074
Phase IV: Data Reduction

Yellow Line Retroreflectivity

Average retroreflectivity = \(-22.459 \ln(\text{# of cumulative vehicle passes in '000}) + 224.78\)

\(R^2 = 0.4466\)
Phase IV: Data Reduction

- **Findings**
  - Large Data Sets – more accurate degradation models.
  - Use of FHWA recommended minimum retroreflectivity values:
    - Non-Freeway White Line:  \( X=3100, \ R^2=0.60 \)
    - Non-Freeway Yellow Line:  \( X=1230, \ R^2=0.45 \)
    - Freeway White Line:  \( X=570, \ R^2=0.35 \)
    - Freeway Yellow Line:  \( X=540, \ R^2=0.05 \)
  - \( X=\# \) of cumulative vehicle passes in 1000’s of vehicles
Phase IV: Data Reduction

- Additional Analysis:
  - Additional readings required for analysis of degradation in polyurea and epoxy markings.
  - Examine data sets for anomalous readings.
  - To include other independent variables such as average snowfall amounts, pavement types, raw data, curved vs. straight sections.
Remaining Phases

- Phase V: Economic Analysis of life cycle costs.
- Phase VI: An evaluation of the deterioration mechanisms of the performance factors.
- Phase VII: Final Report.
Questions?
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