Minnesota Disk-Shaped Compact Tension Testing (DCT)

Chelsea Hanson

Swedish Transport Administration Meeting

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Why do we need to specify Low Temperature Cracking performance of asphalt mix?

- Binder is important, but does not completely control material behavior:
  - Aggregate/mastic effects on mixture creep/fracture properties
  - Effects of RAP, RAS, WMA, and other additives
  - Mixture volumetrics and aggregate effects – voids, aggregate size and gradation
  - Plant/field aging
What is the DCT Test?

- Disk-Shaped Compact Tension Test (DCT)
- Low-temperature performance test for asphalt mixtures
- Determines fracture energy ($G_f$), measured in J/m$^2$
  - Measure of a mixture’s resistance to cracking
- Recommended by low-temperature cracking pooled fund study to measure thermal fracture resistance
**Disk-Shaped Compact Tension, DCT Test**

- ASTM D7313-13
- Loading Rate:
  - Crack Mouth Opening Displacement
  - CMOD = 0.017mm/s (~1.0-mm/min)
- Measurements:
  - CMOD
  - Load

\[ G_f = \frac{\text{Fracture Work}}{\text{Fracture Area}} \]
Results for TH371 Sections

Field Cores (TH371)
RP6: Good performing section (2005 construction)
RP17/21.5: Poor performing section (2004 construction)

<table>
<thead>
<tr>
<th>RP</th>
<th>North Bound Crack Count</th>
<th>South Bound Crack Count</th>
<th>Fracture Energy [J/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>3</td>
<td>4</td>
<td>453.44</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>8</td>
<td>356.18</td>
</tr>
<tr>
<td>21.5</td>
<td>10</td>
<td>57</td>
<td>330.59</td>
</tr>
</tbody>
</table>
Field Core Testing

A = TH 1  (Dist. 1)
B = TH 2  (Dist. 2)
C = TH 6  (Dist. 3)
D = TH 6  (Dist. 2)
E = TH 9  (Dist. 2)
F = CSAH 10 (Dist. 1)
G = TH 10 (Dist. 3)
H = TH 10 (Dist. 4)
I = TH 25 (Dist. 3)
J = TH 27 (Dist. 3)
K = TH 28 (Dist. 4)
L = CSAH 30 (Metro)
M = I-35  (Metro)
N = TH 53 (Dist. 1)
O = TH 113 (Dist. 2)
P = TH 210 (Dist. 3)
Q = TH 212 (Metro)
R = TH 220 (Dist. 2)
Field Cracking Performance vs. Fracture Energy
Refinement and Implementation of Specification

Implementation of Performance-based Specification (MnDOT)

Pilot Implementation

Refinement Efforts (Spec. finalization, conditioning process, training etc.)

Draft Spec. Development
Refinement and Implementation of Specification

Implementation of Performance-based Specification (MnDOT)

- Draft Spec. Development
- Refinement Efforts (Spec. finalization, conditioning process, training etc.)
- Pilot Implementation
Projects

- Variety of climates, binders, construction
  - D2 – TH 310, FDR + Overlay, PG 58-34
  - D3 – TH 371, Reconstruct, PG 64-34
  - Metro – TH 10, Mill & Overlay, PG 64-28
  - D6 – TH 56, SFDR + Overlay, PG 58-34
  - D6 – TH 69, Mill & Overlay, PG 58-28
Summary

- 2 projects (TH10 and TH371) passed at mix design
  - Both Level 4 designs (Higher amounts of crushed agg.)
  - Both polymer modified

- 3 failed at mix design
  - TH 69, 58-28, 30% RAP, 324 J/m²
  - Adj. 58-34, 20% RAP, 549 J/m²
  - TH 56, 58-34, 20 % RAP, 292 J/m²
    - Adj. + 0.1% new AC, 310 J/m²
  - TH 310, 58-34, 20% RAP, 257 J/m²
    - Adj. 58-34, 0% RAP, 317 J/m²
    - Old oil in mix design, 195 J/m²

- Need to make sure that same materials are used for mix design and production (esp. binder)
Possible Mixture Adjustments

- Binder grade
  - Reduce low PG (-34 vs -28)
- Different modifier or supplier
- Aggregate source and crushing
  - Granite/taconite instead of limestone
- Aggregate Gradation
  - Finer gradation
  - Increase binder content
Refinement and Implementation of Specification

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Refinement and Implementation of Specification

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Implementation of Performance-based Specification (MnDOT)
MnDOT DCT Specifications

- “MnDOT Modified”
  - Current version used by MnDOT

- GOAL: Improve ease, practicality and repeatability of test procedure

- Several changes/additions to ASTM specification

- Revisions made to temperature conditioning of specimens:
  - Specimens must reach test temperature in no faster than 0.75 hours, but within 1.5 hours.
  - Specimens must stay in conditioning chamber for a minimum of 2 hours before testing.
  - All testing must be finished within 5 hours of initial placement into conditioning chamber
Refinement and Implementation of Specification

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- Draft Spec. Development
- Refinement Efforts (Spec. finalization, conditioning process, training etc.)
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Round Robin Study

- Inter-laboratory reproducibility study
  - Samples collected during Summer/Fall 2014, with testing completed in Spring of 2015
- 16 projects selected from around the state
- Participating labs included AET, Braun, and MnDOT
Average Fracture Energies: All Labs
Average Fracture Energies: All Projects with XX-34 Binder
DCT Provision Highlights

- Project Selection
- Design
- Production
- Sampling
Project Selection

- Goal is to include DCT testing, by Special Provision, in approximately 3 projects in 2016.
- Include on New Construction or Reconstruction only.
- DCT requirement on Wear Mix only (top 4”)
- Minimum Wear mixture approx. 20,000 tons.
- Pre-Bid Meeting
Overview DCT Pilot Specification

- Initial Mixture Design Report
  - Preliminary Mixture Design Report (MDR)
- Initial DCT Verification
  - Verify plant produced mixture meets minimum requirements
- Final Mixture Design Report
- Additional Sampling
Mix Design Requirements

- Mix design submittal must include fracture energy results for wearing course mixture.
- Wear Course mixture only (Top 4”) PG XX-34
- Minimum Design Fracture Energy
  - Traffic Level 2 & 3 Fracture Energy 450 J/m²
  - Traffic Level 4 & 5 Fracture Energy 500 J/m²

![Average Fracture Energies: All Projects with XX-34 Binder](chart.png)
**Asphalt Binder Ratio Modification**

- Modified Ratio of Added Asphalt/Total Asphalt from 80% to 75%.

<table>
<thead>
<tr>
<th>Specified Asphalt Grade</th>
<th>Recycled Material</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>RAS Only</td>
</tr>
<tr>
<td>PG XX-28, PG 52-34, PG 49-34, PG 64-22</td>
<td>70</td>
</tr>
<tr>
<td>Wear</td>
<td>70</td>
</tr>
<tr>
<td>Non-Wear</td>
<td></td>
</tr>
<tr>
<td>PG 58-34, PG 64-34, PG 70-34</td>
<td></td>
</tr>
<tr>
<td>Wear &amp; Non-Wear</td>
<td>75</td>
</tr>
</tbody>
</table>

1 The ratio of added new asphalt binder to total asphalt binder is calculated as (added binder/total binder) x 100
Initial DCT Verification

- Full-scale production of the wearing mixture can’t begin until fracture energy of plant produced mix has been verified.
  - Verify mixture by placing mix on the project or at an alternate location.
    - When placed on the project, production mix will be limited to between 50 and 200 tons.
      - Suggestion:
        - With approval of Engineer substitute Wear mix (with correct asphalt grade) while placing non-Wear mixture.
Final MDR

- A Final MDR, allowing full-scale production, will be issued based on successful verification of plant produced mixture.

<table>
<thead>
<tr>
<th>Traffic Level/PG Grade</th>
<th>Fracture Energy (J/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Level 2-3/PG XX-34</td>
<td>400</td>
</tr>
<tr>
<td>Traffic Level 4-5/PGXX-34</td>
<td>450</td>
</tr>
</tbody>
</table>

### Allowable Differences of Test Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Allowable Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCT - Fracture Energy (J/m²)</td>
<td>90</td>
</tr>
</tbody>
</table>
Fracture Energy Testing During Production

Required when:

- An aggregate proportion change for a single stockpile aggregate greater than 10% from the currently produced mixture.
- A cumulative change on any one aggregate product exceeds 10% from the original MDR.
- A change in added asphalt that decreases by more than 0.3% below that shown on the MDR.
- An aggregate or RAP source is changed.
- An increase of 5% in RAP content or 1% in RAS content.
- A change in binder suppliers or sources.

*For each day of wear course production obtain at least five (5) full 6” x 12” cylinders for the Department. These samples will be for information only.
Future Efforts

- Implementation of DCT Pilot spec on ~ 3 construction projects during the 2016 construction season
- Continue to populate the DCT results database
  - Test and record results of specimens collected during 2015 construction season
- Hold Pre-Bid Meeting with contractors
Thank you for your attention

Questions?

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- Bill Buttlar
- Contractors
- Producers
- Dave Van Deusen
- Shongtao Dai
- Joe Voels
- Dave Linell
- Luke Johanneck

Contact:
John Garrity
John.garrity@state.mn.us
651-366-5577

Chelsea Hanson
Chelsea.hanson@state.mn.us
651-366-5482

Dave Van Deusen
dave.vandeusen@state.mn.us
651-366-5524

Sponsoring agencies for present work:
US Department of Transportation (FHWA)
Minnesota Department of Transportation
Summary

- Fracture energy has and is continuing to show high potential as cracking performance indicator
- Stay tuned:
  - 2015: Improve breadth of DCT result database
  - 2016: Continue with pilot projects
  - 2017: Goal of implementation
    - Plan to target wear courses
    - New and re-construction
    - Possibly on thick overlays
- Stand-alone testing equipment is available
Effects of Mix Composition on Fracture Energy

- Fracture Energy (J/m²) vs. Asphalt Binder (%)
- Fracture Energy (J/m²) vs. VMA (%)
- Fracture Energy (J/m²) vs. Adj. Asphalt Film Thickness (micron)
Fracture Area = Thickness * Length (initial ligament length)
### LTC Performance Specifications

- Based on traffic levels

<table>
<thead>
<tr>
<th>Limits</th>
<th>Project Criticality / Traffic Level</th>
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<tbody>
<tr>
<td></td>
<td>High (&gt; 30M ESALs)</td>
</tr>
<tr>
<td>DCT Fracture Energy (J/m²)</td>
<td>690</td>
</tr>
<tr>
<td></td>
<td>Medium (10 – 30M ESALs)</td>
</tr>
<tr>
<td></td>
<td>460</td>
</tr>
<tr>
<td></td>
<td>Low (&lt; 10M ESALs)</td>
</tr>
<tr>
<td></td>
<td>400</td>
</tr>
<tr>
<td>IlliTC Cracking Prediction (m/km)</td>
<td>&lt; 4</td>
</tr>
<tr>
<td></td>
<td>&lt; 64</td>
</tr>
<tr>
<td></td>
<td>Not required</td>
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Marasteanu et al., 2012
On-going Work

- Use of validator to ensure test correctness
- Training of lab staff
- Round robin (inter-laboratory) repeatability study
  - *Samples collected this fall, with testing to start this spring*
- Participating labs include AET, Braun, MnDOT, and UMD
On-going Work

- Study analyzing source of drop in fracture energy from mix design to production and placement
- Samples collected from 8 projects throughout the state
Average Fracture Energies: All Labs with all Four Specimens “Surviving” Test
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Table 2360-8

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