A SIMPLE TEST TO DETERMINE WORKABILITY OF ASPHALT CONCRETE – PROGRESS REPORT

**DONGRE WORKABILITY TEST (DWT)**

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Outline

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  • Theoretical Considerations
• Findings?
  • Validation of Field Compaction Temperature Prediction
  • Effect of RAS and RAP on Workability
  • Use of DWT during Paving
  • Effect of Aging on Workability
  • Effect of Workability additives on Plant Mix Crumb Rubber Mixes
• Conclusions
What Was Accomplished? - Summary

- DWT was used to test mixes laid on FHWA ALF test lanes
  - 11 lanes were constructed at the FHWA ALF
  - These 11 mixes were tested using DWT protocol to determine
    - Effect of RAP on Workability
    - Effect of RAS on Workability
    - Effect of Aging on Workability (oven storage)
    - Validation of Field Compaction Temperatures
    - Possible use of DWT during Paving.
# FHWA ALF Test Lanes Details

<table>
<thead>
<tr>
<th>ALF Lane #</th>
<th>% ABR</th>
<th>Virgin PG Grade</th>
<th>Drum Discharge Temperature</th>
<th>WMA Process</th>
<th>Paving Date</th>
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<td></td>
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<td>RAP</td>
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<td>0</td>
<td>64-22</td>
<td>64-22</td>
<td>300-320</td>
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<td>20</td>
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<td>Evotherm</td>
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<td>4</td>
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<td>300-320</td>
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<td>300-320</td>
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<td>300-320</td>
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<tr>
<td>7</td>
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<td>20</td>
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<td>240-285</td>
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<tr>
<td>8</td>
<td>40</td>
<td>58-28</td>
<td>58-28</td>
<td>300-320</td>
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<td>20</td>
<td>64-22</td>
<td>64-22</td>
<td>240-285</td>
<td>Water Foaming</td>
</tr>
<tr>
<td>10</td>
<td>40</td>
<td>58-28</td>
<td>58-28</td>
<td>240-270</td>
<td>Evotherm</td>
</tr>
</tbody>
</table>
What is DWT? - Background

• A simple test method (DWT) was developed to determine workability of asphalt mixes
  • Uses Superpave Gyratory Compactor
  • Loose mix is tested
    • Test is done prior to gyratory compaction of mix design specimen
    • After the DWT test is complete Specimen is compacted normally with specified gyrations to get volumetrics
    • Requires new software for the gyratory compactor
  
• DWT is simple and transparent to the operator
  • Rodding of the loose mix prior to testing is required

• DWT is sensitive to
  • WMA, HMA, Polymer modified HMA, Temperature
DWT Test

• Cost?
  • It depends!
  • If you have a Gyratory Compactor
    • Machine control and data analysis Software
      • from Pine Instruments
  • If you do not have a Gyratory Compactor
    • I am talking with Pine about making a low cost DWT device
      • Good for Asia and Europe etc

• DWT Test Required Equipment
  • Software
  • Gyratory Compactor
DWT Testing Protocol

• Loose Mix is Tested at 0.05 mm/s Ram Rate
• 4810 g of Asphalt Mixture
  • Mix design (115 mm gyratory specimen)
  • 2 replicates recommended
• The top plate, the mold are all heated to test temp
• Test is stopped at 700 kPa
• Workability is determined as:
  • Slope of the Volumetric Strain (%) and Stress (kPa) at 600 kPa stress level
  • Currently the slope is between 550 kPa and 650 kPa
  • Repeatability is good
Test Temperature = 300°F
Asphalt: PG 64-22
Aggregate: VA Diabase

Workability = Slope at 600 kPa

Stress, kPa
Volumetric Strain, %

0.05 mm/s 0.01 mm/s
Test Rate: 0.05 mm/s
Asphalt: PG 64-22
Aggregate: VA Diabase
So What?

- OK! So we have a way to measure workability
  - So What?
- Determination of Field Compaction Temperatures
  - Currently it is field experience and test strip based
- Determination of Temperature Reduction obtained using WMA additives
  - Currently experience based
  - No way to verify in the lab
- A method has been developed
  - Similar to the old viscosity based method
  - Determine workability at two temperatures (145°F and 225°F)
  - Use chart to determine the field compaction temperature and/or temperature reduction obtained from WMA additives
281 kPa = Dry mix (no binder) Workability Limit

170 kPa = Upper Field Compaction Temperature Limit

150 kPa = Lower Field Compaction Temperature Limit
<table>
<thead>
<tr>
<th>Asphalt Source</th>
<th>Aggregate Source</th>
<th>Mix Type</th>
<th>Predicted Field Compaction Temperature, °F</th>
<th>Actual Field Compaction Temperature °F</th>
<th>Time Available For Compaction (TAC), minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-22+ADV</td>
<td>VA Diabase</td>
<td>WMA - Advera</td>
<td>192</td>
<td>228</td>
<td>23</td>
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<tr>
<td>64-22+M1</td>
<td>VA Diabase</td>
<td>WMA - Evotherm</td>
<td>203</td>
<td>233</td>
<td>17</td>
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<tr>
<td>64-22+SAS</td>
<td>VA Diabase</td>
<td>WMA - Sasobit</td>
<td>185</td>
<td>221</td>
<td>26</td>
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<tr>
<td>82-22</td>
<td>VA Diabase</td>
<td>PMB</td>
<td>230</td>
<td>335</td>
<td>37</td>
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<tr>
<td>CRMB</td>
<td>N/A</td>
<td>WMA - CRMB + Sasobit</td>
<td>170</td>
<td>211</td>
<td>21</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td>176°F</td>
<td></td>
</tr>
<tr>
<td>PG 70-22</td>
<td>MO</td>
<td>PMB</td>
<td>237</td>
<td>328</td>
<td>37</td>
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<td>PG 70-28</td>
<td>VA Diabase</td>
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<td>248</td>
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<td>PG 76-22</td>
<td>VA Diabase</td>
<td>PMB -2</td>
<td>225</td>
<td>258</td>
<td>13</td>
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<td>PG 94-22</td>
<td>NCAT N7-3</td>
<td>PMB</td>
<td>229</td>
<td>253</td>
<td>10</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>240°F</td>
<td></td>
</tr>
<tr>
<td>PG 76-22-Foamed</td>
<td>VADOT</td>
<td>Std. PMB</td>
<td>162</td>
<td>178</td>
<td>215 - 190°F</td>
</tr>
<tr>
<td>PG 76-22-Foamed</td>
<td>VADOT</td>
<td>SBS+PE</td>
<td>170</td>
<td>190</td>
<td>220 - 200°F</td>
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<tr>
<td>PG 76-22-Foamed</td>
<td>VADOT</td>
<td>TB Rubber</td>
<td>171</td>
<td>183</td>
<td>N/A</td>
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</tbody>
</table>

Asphalt Source
Aggregate Source
Mix Type
Predicted Field Compaction Temperature, °F
Actual Field Compaction Temperature °F
Time Available For Compaction (TAC), minutes
Summer  Winter
Implementation Proposal – Mix Production QC

- We can implement the DWT Test as follows
  - Before compacting a QC volumetric specimen using the Gyratory Compactor do the DWT test first by loading the loose mix to 700 kPa at 0.05 mm/s
    - Currently the loose mix is loaded to 600 kPa at 8.4 mm/s
  - This change will be transparent to the user but will provide additional DWT information that can be used in QC testing rapidly
  - The compaction can proceed normally (as is done now) once 600 kPa load is reached at 0.05 mm/s and the operator chooses to proceed
    - if the DWT value is within limits
    - DWT value and limits pre-determined during mix design
The BIG QUESTION!

• How are SGC volumetric parameters affected if DWT is conducted prior to compacting a volumetric QC specimen?
  • Air Voids √
  • Gmb
  • Final Height
  • Initial Height
Effect on SGC Air Voids

![Graph showing the effect on SGC Air Voids with AMRL Mix Number on the x-axis and Air Voids, % on the y-axis. The graph compares AMRL Proficiency Data + 1 Std. Dev., DWT + Compaction Air Voids, and AMRL Proficiency Data - 1 Std. Dev.](image-url)
Theoretical Considerations

• Koneru et al., Research
  • Developed Constitutive equation for loose (uncompacted) mix
    • Gyratory mold geometry
    • Creep and stress relaxation type loading
    • Constitutive Equation is based on six parameters (vis., shear modulus etc.)
    • Six parameters estimated from Gyratory compaction curve (ht vs N)
    • Gyratory compaction curve predicted using FEM and the six parameters!!
  • Koneru et al., used the Gyratory compaction curve to estimate the six parameters because “no suitable test method available to characterize loose mix at the time”
• Now, DWT is available!
Theoretical Considerations

• Theoretical Analysis – What is Needed?
  • Can the DWT stress-Strain curve be used with FEM method developed by Texas A&M
    • Modelling of Hot-Mix Asphalt Compaction – Koneru et al.

• Modelling of DWT Stress-Strain Curves
  • Need constitutive equation similar to that developed by Koneru et al., but for strain rate type DWT test
  • The parameters can then be determined and used in the Koneru FEM analysis to predict Gyratory compaction and field pavement compaction.

• Analysis in progress!
• But in the mean time…..
Theoretical Considerations

- Koneru et al., Research
  - Developed Constitutive equation for loose (uncompacted) mix
    - Gyratory mold geometry
    - Creep and stress relaxation type loading
    - Constitutive Equation is based on six parameters (vis., shear modulus etc.)
    - Six parameters estimated from Gyratory compaction curve (ht vs N)
    - Gyratory compaction curve predicted using FEM and the six parameters!!
  - Koneru et al., used the Gyratory compaction curve to estimate the six parameters because “no suitable test method available to characterize loose mix at the time”

- Theoretical Analysis
  - Can the DWT stress-Strain curve be used with FEM method developed by Texas A&M
    - Modelling of Hot-Mix Asphalt Compaction – Koneru et al.

- Modelling of DWT Stress-Strain Curves
  - It appears that the DWT curve maybe related to the gradation curve
  - For example: Early attempts indicate that the inverse of 0.45 power maybe used to fit the linear portion of the DWT curve!
First Gyratory Compaction Curves were fitted to:

\[ H_{Fin} = A \ln(N_G) + H_{INIT} \]

Where,

- \( H_{Fin} \) = Final Compacted Height, mm
- \( H_{INIT} \) = Initial Height at 600 kPa, mm
- \( N_G \) = Number of Gyrations

Next the parameter ‘A’ in the above equation compared to the DWT value.
DWT value versus ‘A’ – Single sample

\[ y = 4 \times 10^{-5}x^2 - 0.0237x + 8.5958 \]

\[ R^2 = 0.9842 \]
DWT value versus ‘A’ – All Data

\[ y = -5 \times 10^{-5} x^2 + 0.0073x + 6.1692 \]

\[ R^2 = 0.8198 \]
### Validation of Field Compaction Temperature Prediction

<table>
<thead>
<tr>
<th>FHWA ALF Lane No.</th>
<th>Mix Type</th>
<th>Binder</th>
<th>WMA/HMA Technology</th>
<th>DWT Prediction of Compaction Temperatures, °F</th>
<th>Field Temperature Data from ALF Construction, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td>Breakdown (DWT = 170 kPa)</td>
<td>Finishing (DWT = 150 kPa)</td>
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<tr>
<td>L2</td>
<td>40% RAP</td>
<td>PG 58-28</td>
<td>WMA/Foaming</td>
<td>208</td>
<td>185</td>
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<td>L7</td>
<td>20% RAS</td>
<td>PG 58-28</td>
<td>HMA</td>
<td>231</td>
<td>197</td>
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<td>L8</td>
<td>40% RAP</td>
<td>PG 58-28</td>
<td>HMA</td>
<td>191</td>
<td>168</td>
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<td>L10</td>
<td>40% RAP</td>
<td>PG 58-28</td>
<td>WMA/Evotherm</td>
<td>190</td>
<td>160</td>
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<tr>
<td>L11</td>
<td>40% RAP</td>
<td>PG 58-28</td>
<td>WMA/Evotherm</td>
<td>204</td>
<td>182</td>
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<tr>
<td>L1</td>
<td>Virgin HMA</td>
<td>PG 64-22</td>
<td>HMA</td>
<td>230</td>
<td>199</td>
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<tr>
<td>L3</td>
<td>20% RAS</td>
<td>PG 64-22</td>
<td>HMA</td>
<td>256</td>
<td>222</td>
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<td>L4</td>
<td>20% RAP</td>
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<td>WMA/Evotherm</td>
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<td>162</td>
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<td>L5</td>
<td>40% RAP</td>
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<td>HMA</td>
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<td>L9</td>
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<td>WMA/Foaming</td>
<td>207</td>
<td>180</td>
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</table>
Validation of Field Compaction Temperature Prediction

Breakdown Roller Temperature, °F

PG 64-22

L1, L3, L4, L5, L6, L9

180, 190, 200, 210, 220, 230, 240, 250, 260, 270
Validation of Field Compaction Temperature Prediction
Effect of RAP on Workability

PG 64-22 with RAP

DWT Predicted Compaction Temperatures, °F

Virgin HMA  20% RAP  40% RAP  20% RAP

HMA

WMA/Evotherm

HMA

WMA/Foaming
Effect of RAP on Workability

**PG 58-28 with 40% RAP**

- **HMA**
- **WMA/Evotherm**
- **WMA/Evotherm**
- **WMA/Foaming**

DWT Predicted Compaction Temperatures, °F
Effect of RAS on Workability

![Graph showing DWT Predicted Compaction Temperatures for PG 58-28, PG 64-22 with 20% RAS and Virgin HMA. The graph compares the temperatures in °F.]
Effect of Aging on Workability - HMA

Test Temperature: 285 °F
Effect of Aging on Workability - WMA

Test Temperature: 285 °F

- Lab Mix WMA EVO 20% RAP
- L9 WMA FOAM 20% RAP
- L4 WMA EVO 20% RAP
Effect of Aging on Workability - WMA

Test Temperature: 245 °F

- L10_EVO 44%RAP
- L11_EVO 44% RAP
- L2_Foam 44%RAP
DWT use during Paving

Lane 1 Test Strips PG 64-22 Virgin Mix HMA

Test Strip 1

Test Strip 2

Lane 1 Accepted
DWT use during Paving

PG 64-22 Lane 9 Test Strips 20%RAP WMA Foam

Test Strip 2
Test Strip 1
Lane 9 Accepted
DWT use during Paving

Lane 3 Test Strips PG 64-22 20% RAS HMA

- Test Strip 1
- Test Strip 2
- Lane 3 - Accepted

DWT Workability Value, kPa
Air Voids, %

3 3.5 4 4.5 5 5.5 6 6.5
DWT use during Paving

PG 58-28 Test Strips 40%RAP HMA

Lane 8 - Accepted

Test Strip 2

Test Strip 1
Conclusions

- DWT is a simple laboratory test, it also has potential application for estimating compaction temperatures and predicting roller patterns as well as a quality control tool.
- The DWT procedure has been shown to provide an asphalt mix workability measure that is sensitive to RAP, RAS and WMA technologies.
- Addition of RAP decreases workability as compared with mix made with virgin aggregates.
  - For high RAP mixes (40% RAP) it was shown using the DWT workability value that the loss in workability may be overcome by selecting a softer binder grade and/or by using WMA technology.
  - The effect of addition of RAP was also successfully identified by DWT method as a reduction in workability thereby predicting higher compaction temperatures as compared to the virgin mix.
Conclusions

• The DWT workability value was able to identify differences in workability induced due to prolonged oven storage (Aging).

• The compaction temperatures predicted using the DWT chart showed reasonable correlation with the field measured breakdown roller compaction temperatures.
Recommendations

• The following recommendations are made for future work toward the use of the DWT procedure:
  • The DWT test method is currently under consideration at ASTM International (ASTM). Continued work towards standardizing the procedure is warranted. Further efforts should include additional refinement of the inputs and a more extensive Inter-Laboratory Study to establish a better the between laboratory precision estimate.
  • Further fine tuning of the 170 kPa (breakdown roller) and 150 kPa (finish roller) prediction limits is needed. This will require measured field compaction temperatures, roller pattern confirmation, field density results, and the correlated DWT values from the laboratory measures. This work should be done on a variety of hot-mix asphalts, warm-mix asphalts, and polymer-modified asphalts. In addition to standard dense mixes, other mix types such as open-graded mixes should also be included.
Recommendations…………..

• Further investigation regarding the use of the DWT value for quality control during production of asphalt mixtures should be considered with special emphasis on establishing a relationship between DWT workability value and roller patterns and temperatures during compaction.
Questions?

• Thank You for Listening!