Concrete CTE

AASHTO Joint Technical Committee on Pavements

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Concrete CTE Concerns

- Frame Calibration
CTE = length change/unit length/degree

122°F
50°F

0.0059
$CTE = \text{length change/unit length/degree}$

$= 0.0026 \text{ in} / 7.0 \text{ in} / 72 \text{ F}$

$= 5.1 \text{ microstrain/F}$
CTE Frame Schematic

- Spring-Loaded LVDT
- Frame Height = 10 in.
- 4-in. Dia. Concrete Core shown
- 3 Semi-Spherical Support Buttons equally spaced about 2-in. Dia. Circle

Front View
Manual CTE Device

304 Stainless Steel
AASHTO TP 60-00

- Typical frames made from invar or stainless steel
- Typical calibration bar made from 304 stainless steel per TP 60 recommendations
- CTE of 304 SS stated as 17.3 x10^{-6}/°C in TP 60
### Independent Lab Results for 304 SS

<table>
<thead>
<tr>
<th>Specimen ID</th>
<th>Avg.CTE (ppm/°C) (50° to 10°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina bisque</td>
<td>5.4+/-0.1</td>
</tr>
<tr>
<td>304 Stainless Steel - Gilson reference bar</td>
<td>16.2+/-0.1</td>
</tr>
<tr>
<td>Titanium</td>
<td>8.9+/-0.1</td>
</tr>
<tr>
<td>304 Stainless Standard - Pine reference bar</td>
<td>15.9+/-0.1</td>
</tr>
<tr>
<td>410 Stainless Steel</td>
<td>10.4+/-0.1</td>
</tr>
<tr>
<td>304 Stainless Steel - manual unit</td>
<td>15.8+/-0.1</td>
</tr>
</tbody>
</table>
Independent Lab Results for 304 SS

TFHRC 304 SS samples

Thermophysical Properties Research Laboratory, Inc.

Figure 2  Mean CTE
Impact of Revised CTE Values

- LTPP Database
- AASHTO TP 60 Test Method
- MEPDG Models
- Testing Results from Other Labs
LTPP Database

- Over 2000 cores tested at TFHRC using 304 SS calibration bar (17.3 used instead of ~15.8)
- Data used by numerous agencies for model development including MEPDG models
AASHTO TP 60

- TP 60 balloted successfully by AASHTO last fall
- Test Method states value of 304 SS as $17.3 \times 10^{-6}/\degree C$
- Test Method does not state that value is different for different temp ranges or different lots of 304 SS
Section X2.1

The test procedure described in Section 7.2 is used to determine a correction factor to account for expansion of the measuring apparatus during the test. A calibration specimen with a known coefficient of thermal expansion should be used. The specimen should be composed of a material that is essentially linearly elastic, noncorroding, non-oxidizing, non porous and nonmagnetic, and it should have a known thermal coefficient as close as possible to that of concrete e.g. a range of 9 to 18 x10-6/oC within the temperature range of 10 to 50 oC (304 stainless steel is a suitable material) An ISO 9001 or equivalent laboratory should determine the CTE of the calibration specimen according to ASTM E 228 or ASTM 289 within the temperature range of 10 to 50 oC and provide a certificate of the CTE value including the lot number of the sample tested.

NOTE: When using version 1.0 of the MEPDG software, AASHTO TP 60-00 (2007) should be used.
MEPDG

- Models based on LTPP data
- CTE is sensitive input for MEPDG and does not have a linear relationship
- Models need to be recalibrated
Effect of CTE on the predicted percent of slabs cracked

\[
y = \frac{104.8}{(1+99628e^{-1.5x})}
\]

\[R^2 = 1.00\]


\[ y = 0.0064x^2 - 0.0381x + 0.0669 \]
\[ R^2 = 0.9999 \]
Predicted Faulting at 90% Reliability

Faulting, in

Pavement age, years

Faulting at 5.5 CTE and 1.5 inch dowel

Faulting Limit

14,187 AADTT

10” JPCP

8” Crushed Stone

A-7-6 Subgrade

Faulting at 5.0 CTE and 1.0 inch dowel
Predicted Faulting at 90 % Reliability

Pavement age, years

Faulting at 4.67 CTE and 1.5 inch dowel
Faulting at 5.5 CTE and 1.5 inch dowel
Faulting Limit
Predicted Faulting at 90 % Reliability

Pavement age, years

Faulting, in

- Faulting at 4.67 CTE and 1.5 inch dowel
- Faulting at 5.5 CTE and 1.5 inch dowel
- Faulting Limit
- Faulting at 4.67 CTE and 1.375 inch dowel
Predicted Faulting at 90 % Reliability

Pavement age, years

- Faulting at 4.67 CTE and 1.5 inch dowel
- Faulting at 5.5 CTE and 1.5 inch dowel
- Faulting Limit
- Faulting at 4.67 CTE and 1.375 inch dowel
- Faulting at 5.5 CTE and 1.375 inch dowel
Predicted Faulting at 90 % Reliability

Pavement age, years

Faulting, in

Faulting at 5.5 CTE and 1.5 inch dowel
Faulting Limit
Faulting at 5.5 CTE and 1.375 inch dowel
Predicted Cracking at 90% reliability

- 4,000 AADTT
- 10” JPCP
- 4” Crushed Stone
- A-7-6 Subgrade

Pavement age, years

Percent slabs cracked, %

Limit percent slabs cracked

10 in thick 6.9 CTE

- Pink line: 10 in thick 6.9 CTE
- Red line: Limit percent slabs cracked
Predicted Cracking at 90 % reliability

Pavement age, years

Percent slabs cracked, %

10 in thick 6.07 CTE  10 in thick 6.9 CTE  Limit percent slabs cracked
Predicted Cracking at 90 % reliability

Pavement age, years

Percent slabs cracked, %

- 10 in thick 6.07 CTE
- 10 in thick 6.9 CTE
- Limit percent slabs cracked
- 9 in thick 6.07 CTE
Predicted Cracking at 90 % reliability

Pavement age, years

Percent slabs cracked, %

- 10 in thick 6.07 CTE
- 10 in thick 6.9 CTE
- Limit percent slabs cracked
- 9 in thick 6.07 CTE
- 9 in thick 6.9 CTE
Predicted Cracking at 90 % reliability

Pavement age, years

Percent slabs cracked, %

- 10 in thick 6.9 CTE
- Limit percent slabs cracked
- 9 in thick 6.9 CTE
Summary

- Current CTE research still valid
- MEPDG ver 1.0 - use CTE based on TP 60 \((17.3 \times 10^{-6}/C\) for 304 SS)
- MEPDG ver 2.0 - use CTE based on new AASHTO Test Method provided models recalibrated
Next Steps

- Adjust values in LTPP Database
- Address CTE issue by AASHTO DARWin-ME Task Force
- Disseminate information to highway industry - timeframe