Creep Compliance Analysis Technique for the Flattened Indirect Tension Test of Asphalt Concrete

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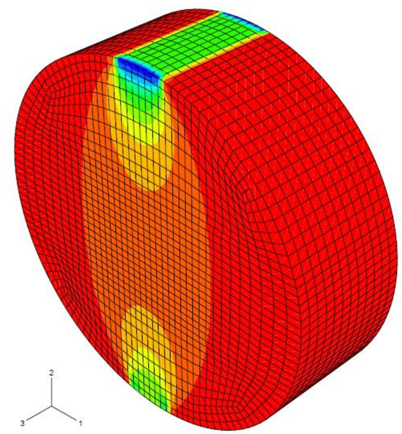
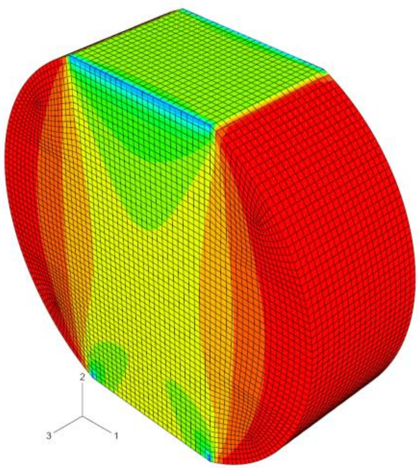
Outline

- Introduction/Motivation
- Objective
- Materials / Test Procedure
- Analysis
- Results
- Concluding remarks





Asphalt Concrete

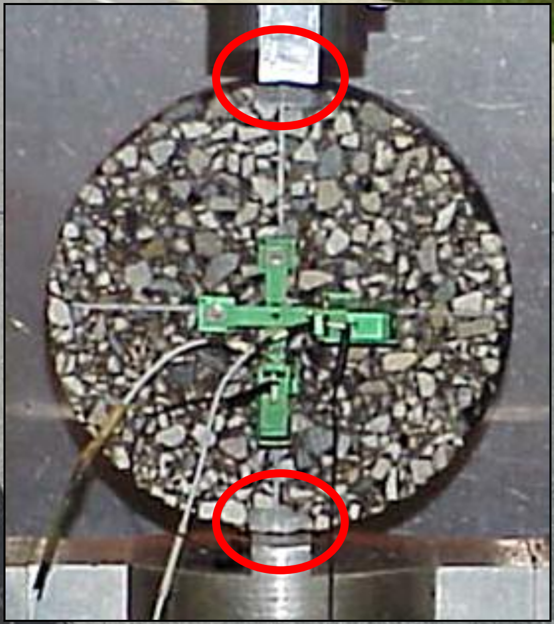
- Constituents:
  - Asphalt Binder
  - Aggregates

- Asphalt Binder:
  - Derived from Crude Oil
  - Many times modified with polymers to enhance properties
  - Undergoes oxidative aging (stiffening) with time
- Asphalt Concrete (Asphalt Mixture)
  - Large fraction produced as hot-mix asphalt (HMA)
  - Most common form of pavement surfacing material (96% of pavement surface in United States)

Motivation

- **Viscoelastic Characterization:**
  - Comparison of Different Materials (Performance)
  - Modeling of Asphalt Pavements
    - *Cracking*
    - *Permanent Deformation*
  - Effects of Aging

- **Field and Lab Samples:**
  - Cored Sample (Cylindrical)
- **Indirect tensile testing (IDT)** (Strength/Creep)
  - AASHTO T-322
    - *Damage under loading heads*



Problem: Crushing underneath loading heads

Solution: Increase contact area

This research reviews use of the "Flattened" geometry for viscoelastic characterization

(Development of suitable geometry (for tensile strength) was discussed previously, *Dave et al. 2007*)

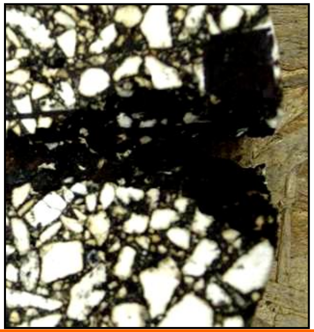
Objectives

- Objective of current work is to develop analysis technique for viscoelastic characterization of material using flattened IDT test geometry
- Analytical solution for flattened geometry has not been proposed
- Hondros solution is applicable to slightly different geometry
- Wang et al. proposed tensile stress prediction equation based on series of numerical solutions
  - Limited to elastic materials
  - Applicable only to limited flattened geometries

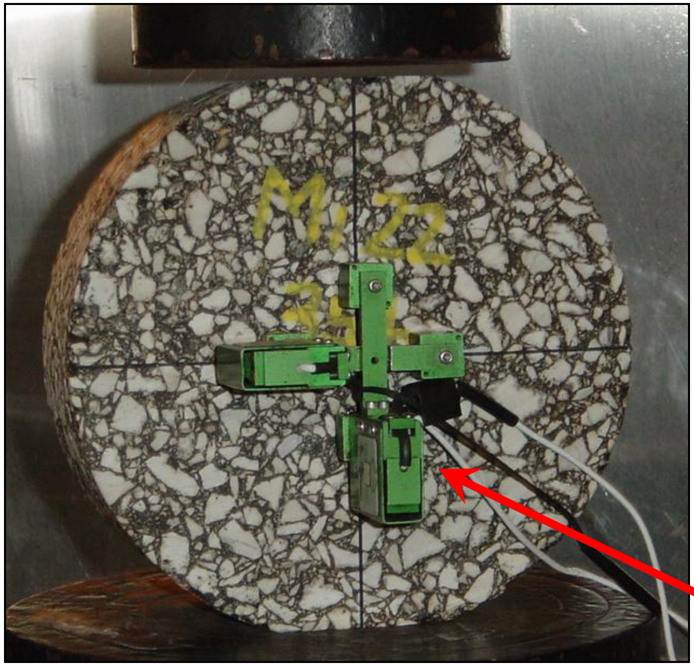
Materials: Wide Range (Stiff → Soft)

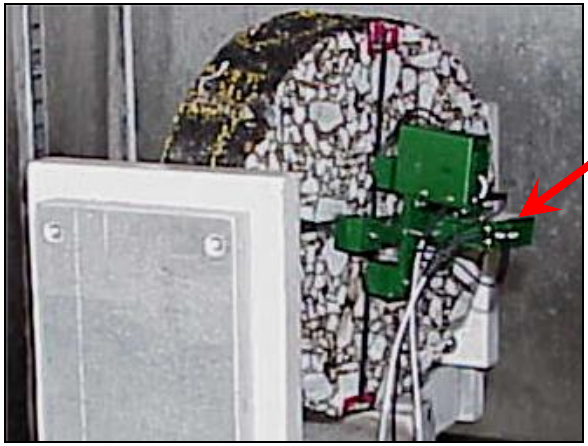
	Mix-22	Mix-28	Mix-40
Aggregate Size	9.5 mm	4.75 mm	4.75 mm
Aggregate Structure	Large	Small	Small
Binder Type	PG64-22	PG58-28	PG58-40
Binder Characteristics	Stiff	Semi-stiff	Soft
Anticipated Regular IDT	No crushing	Possible crushing	Probable crushing

Regular IDT results at -10 deg. C



Indirect Tension Test (IDT)

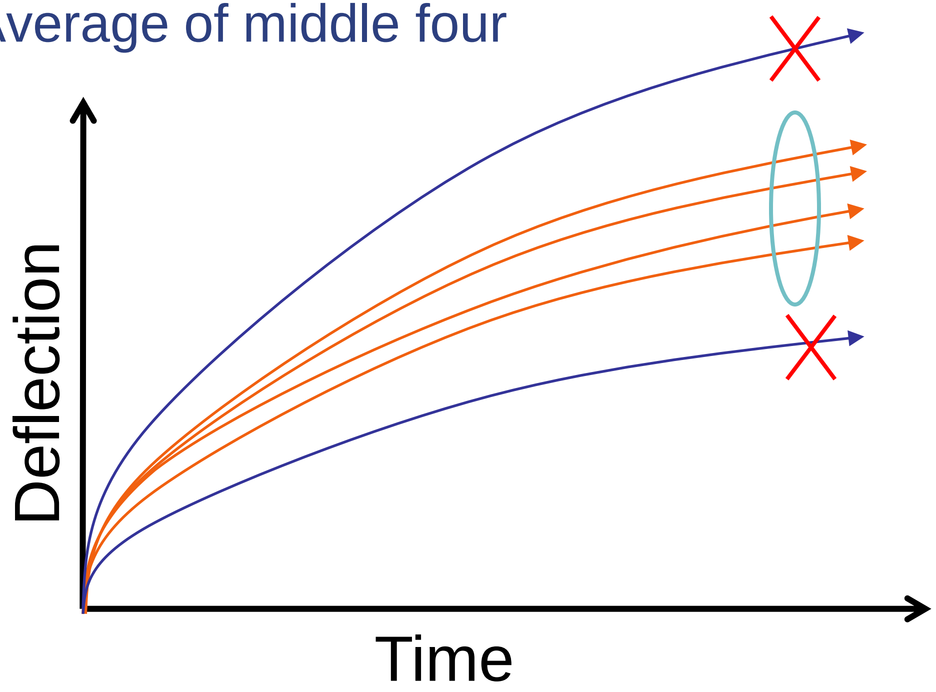




- Regular and Flattened IDT
- 1000-sec creep tests on *three replicates*
- 0, -10, and -20 deg. C
- Displacement measurements
- Diameter: 150 mm
- Thickness: 50 mm
- 4 displacement sensors:
  - *2 horizontal*
  - *2 vertical*
- Gage length: 38.1 mm

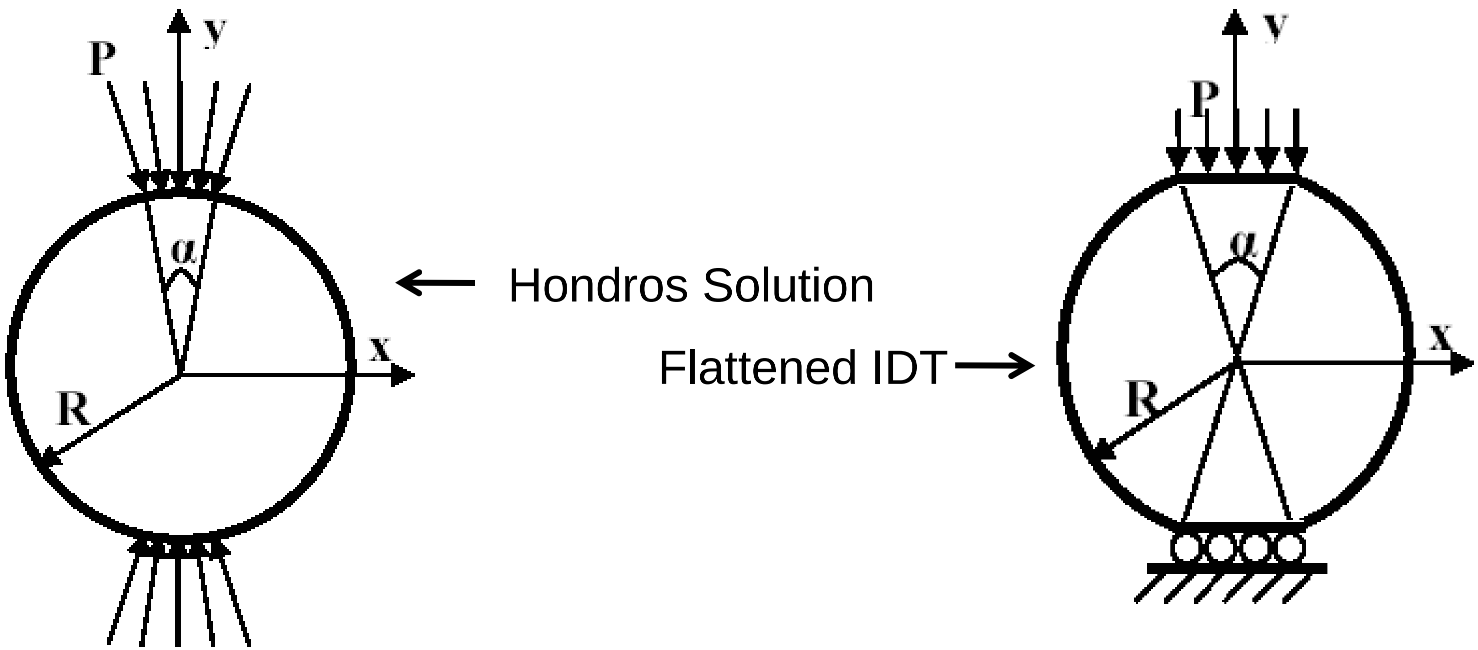
Data Analysis (AASHTO T322)

- Six horizontal and vertical displacements [H(t) and V(t)]
- Displacements were normalized for creep loads, specimen thickness and specimen diameters
- Trimmed average displacements were obtained (similar to AASHTO T322 procedure)
  - Average of middle four



Hondros solution vs. Flattened IDT

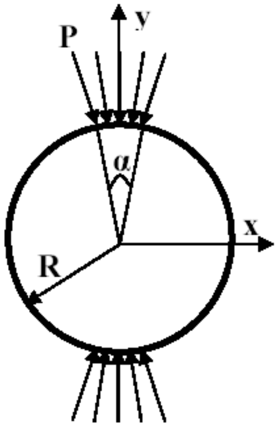
- Bi-axial stress states
- Load applied normal to cylindrical specimen



Hondros, J.R. “The Evaluation of Poisson’s Ratio and the Modulus of Materials of a Low Tensile Resistance by the Brazilian (Indirect Tension) Test with Particular Reference to Concrete,” Austrian Journal of Applied Science, Vol. 10, 243-268, 1959.

Viscoelastic Solution

- Elastic-Viscoelastic Correspondence *Principle (similar to method proposed by Zhang et al.)*
- For Creep Test:
  - $P(t) = P_0\, F(t)$; $F(t)$ = Heaviside Function
- Deformations:



$$H(t) = \frac{K_1}{th.} P_0\, J(t) + \frac{K_2}{th.} P_0\, V(t)$$

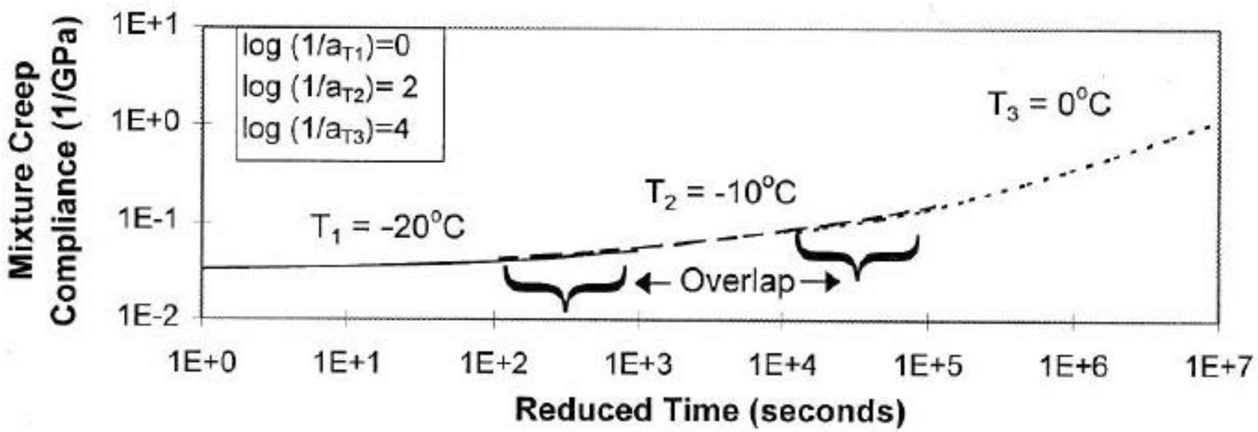
$$V(t) = \frac{K_3}{th.} P_0\, J(t) + \frac{K_4}{th.} P_0\, V(t)$$

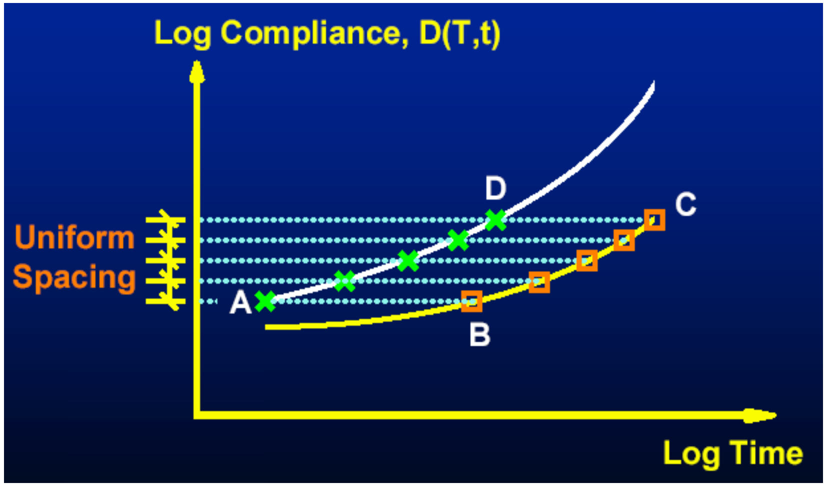
- We can solve for compliances *J(t)* *and V(t)* at each data point
- K_i are the geometric parameters (*α, R, Gage length*)
- *th.* = Specimen thickness

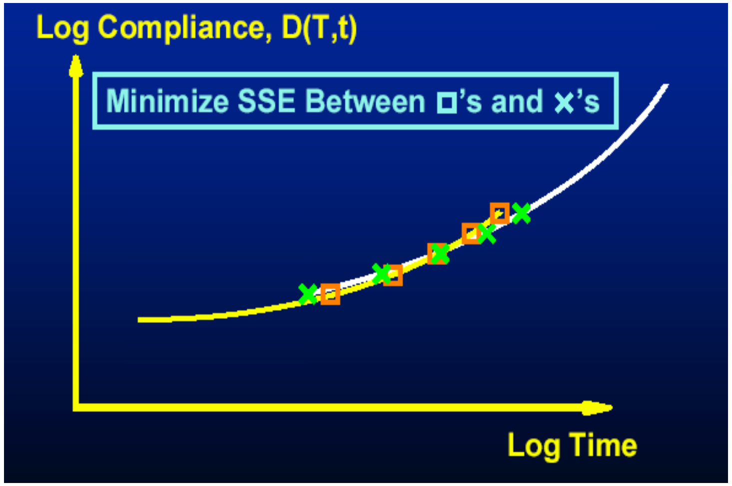
Zhang, W., Drescher, A., Newcomb, D., 1997. Viscoelastic Analysis of Diametral Compression of Asphalt Concrete. *Journal of Engineering Mechanics*, Vol. 123(6): 596:603.

Data Analysis (AASHTO T322)

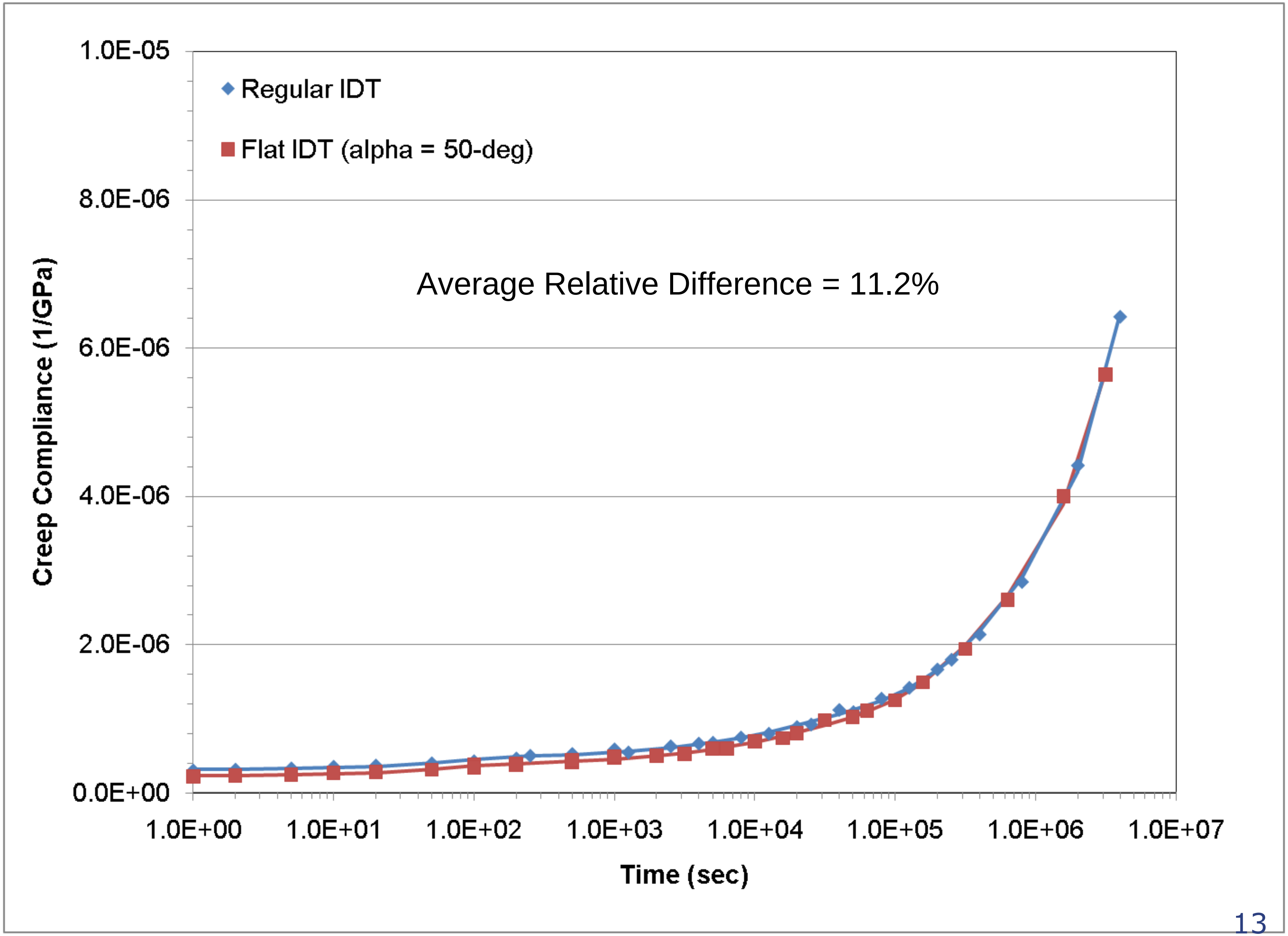
- Time-temperature superposition was performed to generate creep-compliance master-curve





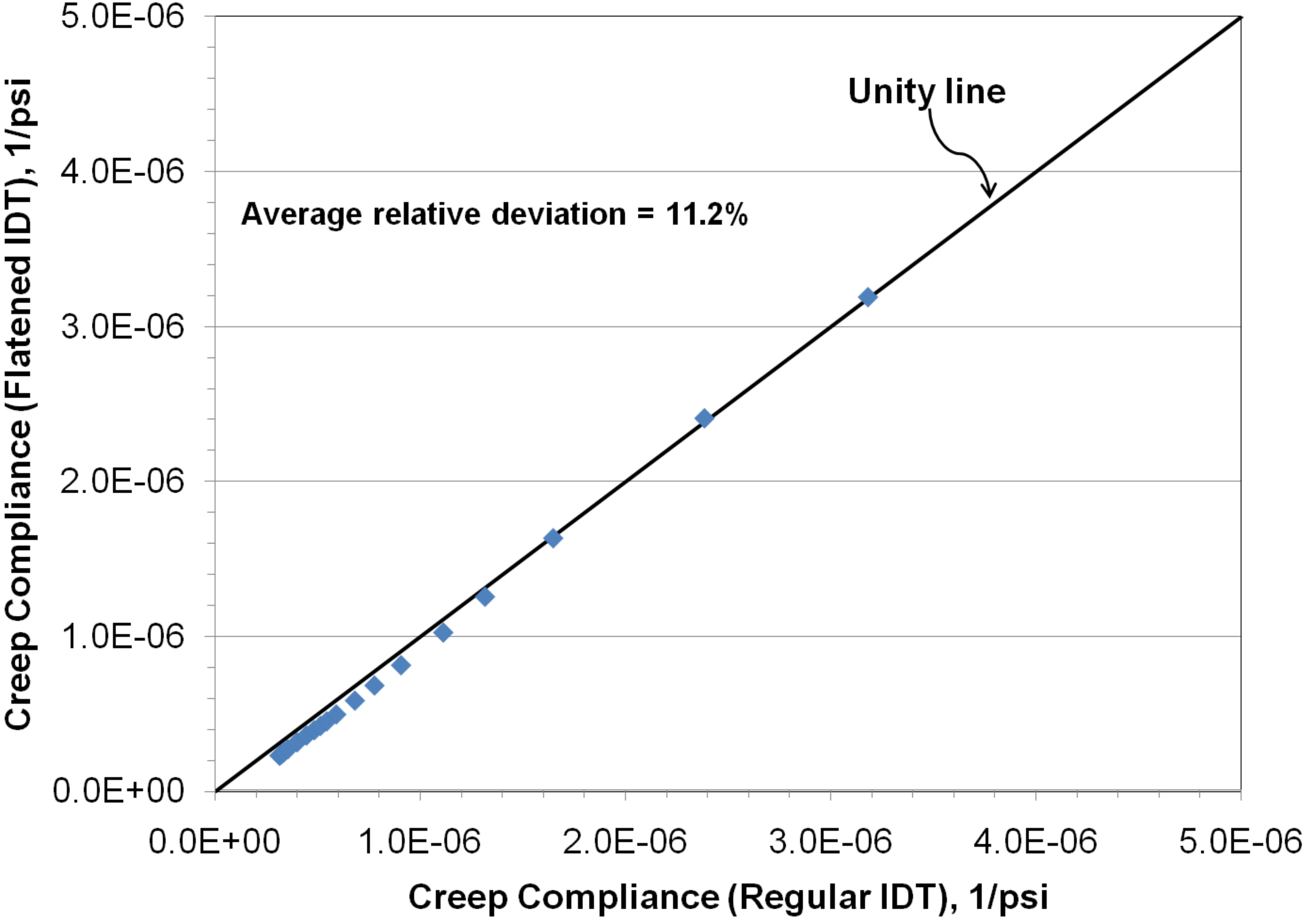


Mix-22



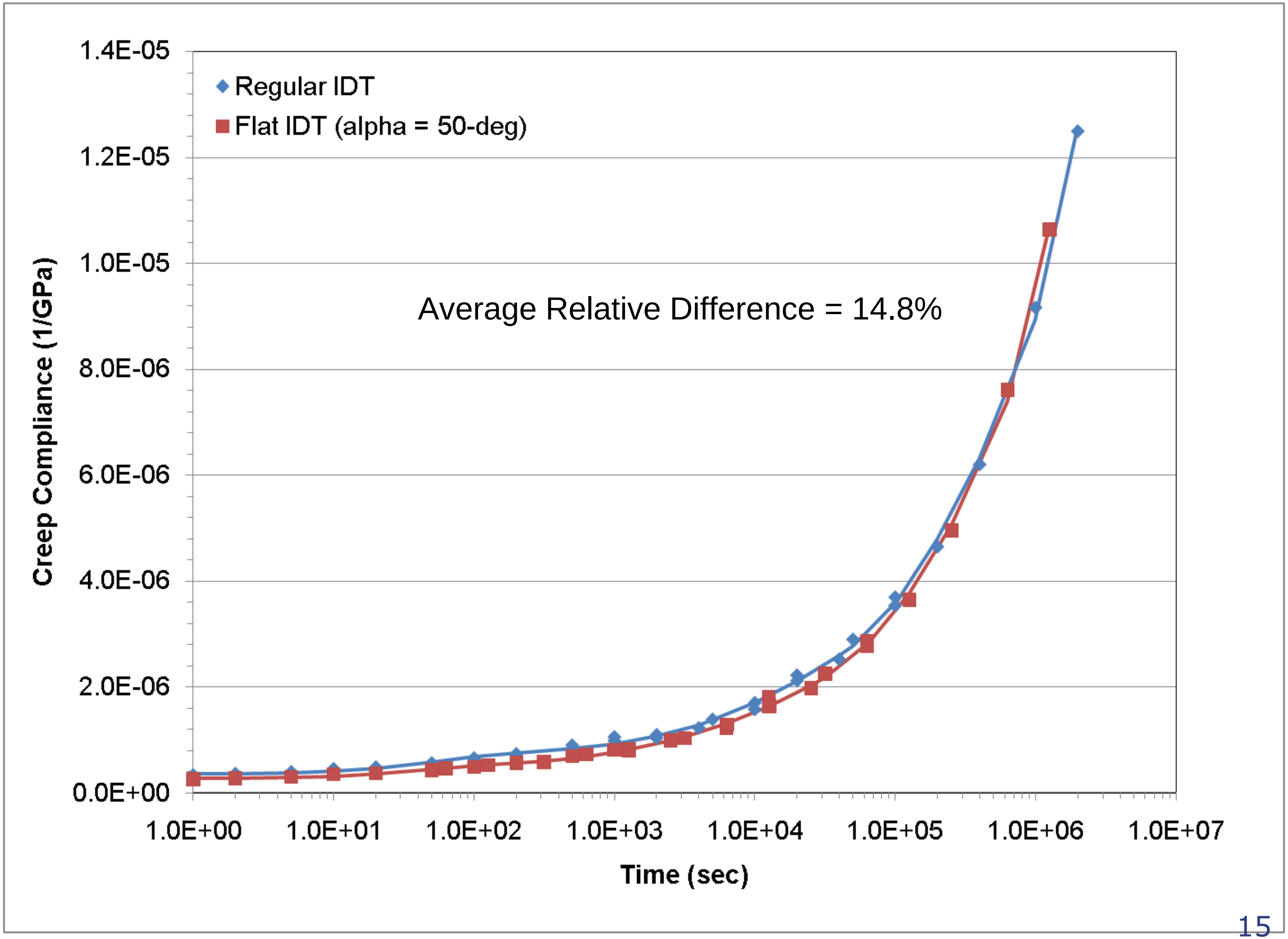
Regular IDT
Flat IDT (alpha = 50-deg)
Average Relative Difference = 11.2%
Creep Compliance (1/GPa)
1.0E-05
8.0E-06
6.0E-06
4.0E-06
2.0E-06
0.0E+00
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05
1.0E+06
1.0E+07
Time (sec)

Mix-22



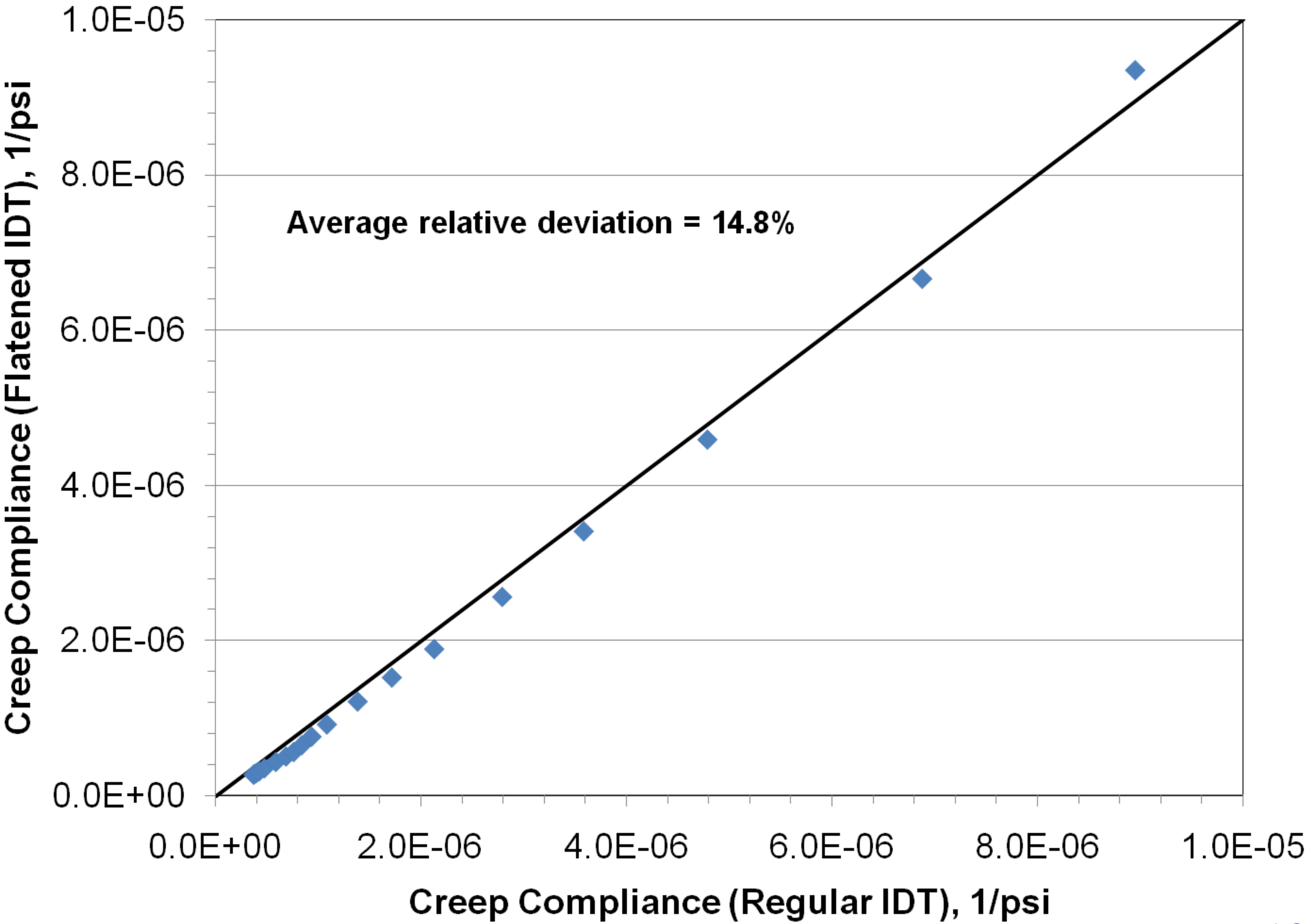
Unity line
Average relative deviation = 11.2%
Creep Compliance (Flatened IDT), 1/psi
Creep Compliance (Regular IDT), 1/psi
0.0E+00
1.0E-06
2.0E-06
3.0E-06
4.0E-06
5.0E-06

Mix-28



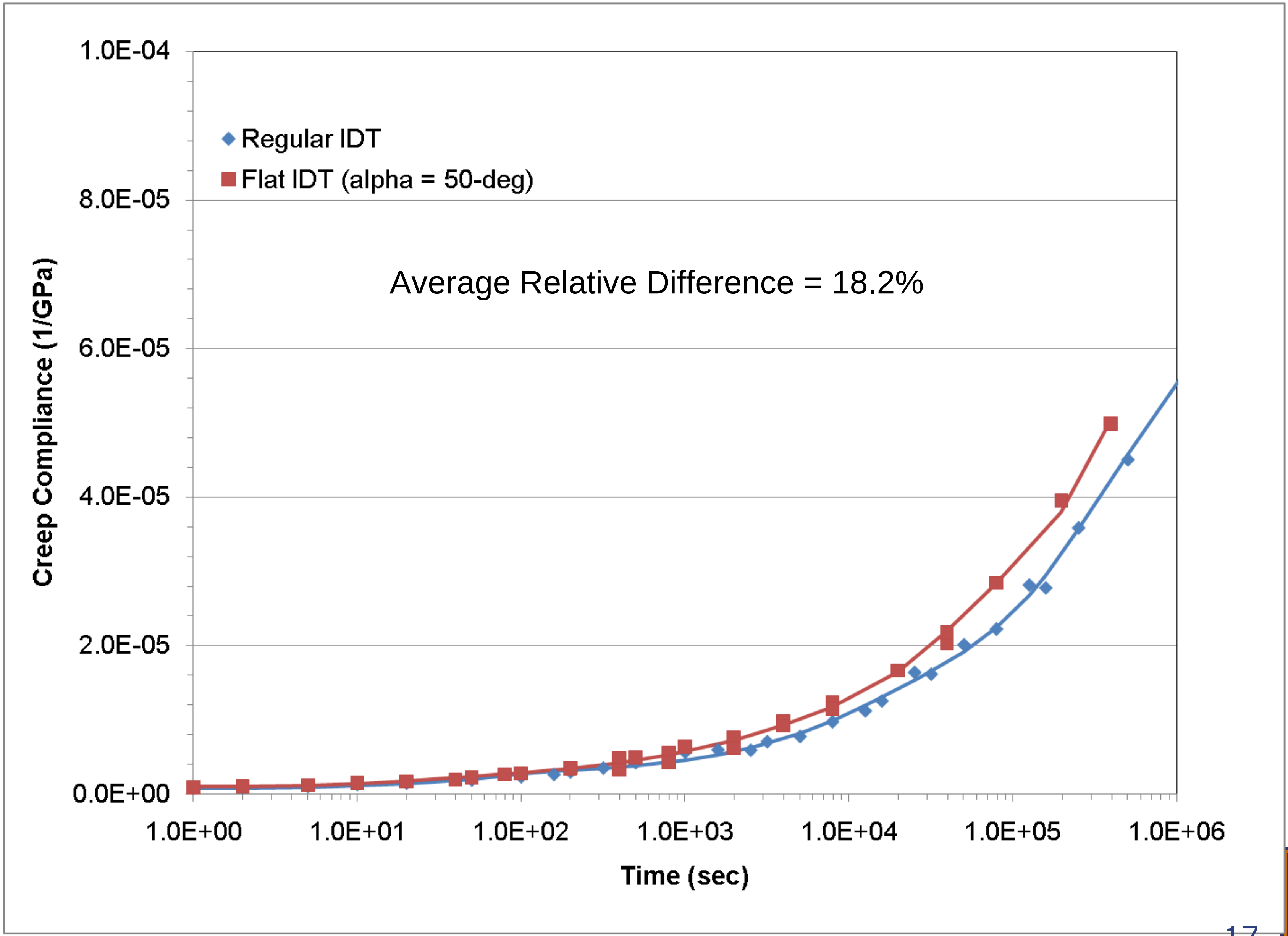
Regular IDT
Flat IDT (alpha = 50-deg)
Average Relative Difference = 14.8%
Creep Compliance (1/GPa)
1.4E-05
1.2E-05
1.0E-05
8.0E-06
6.0E-06
4.0E-06
2.0E-06
0.0E+00
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05
1.0E+06
1.0E+07
Time (sec)

Mix-28



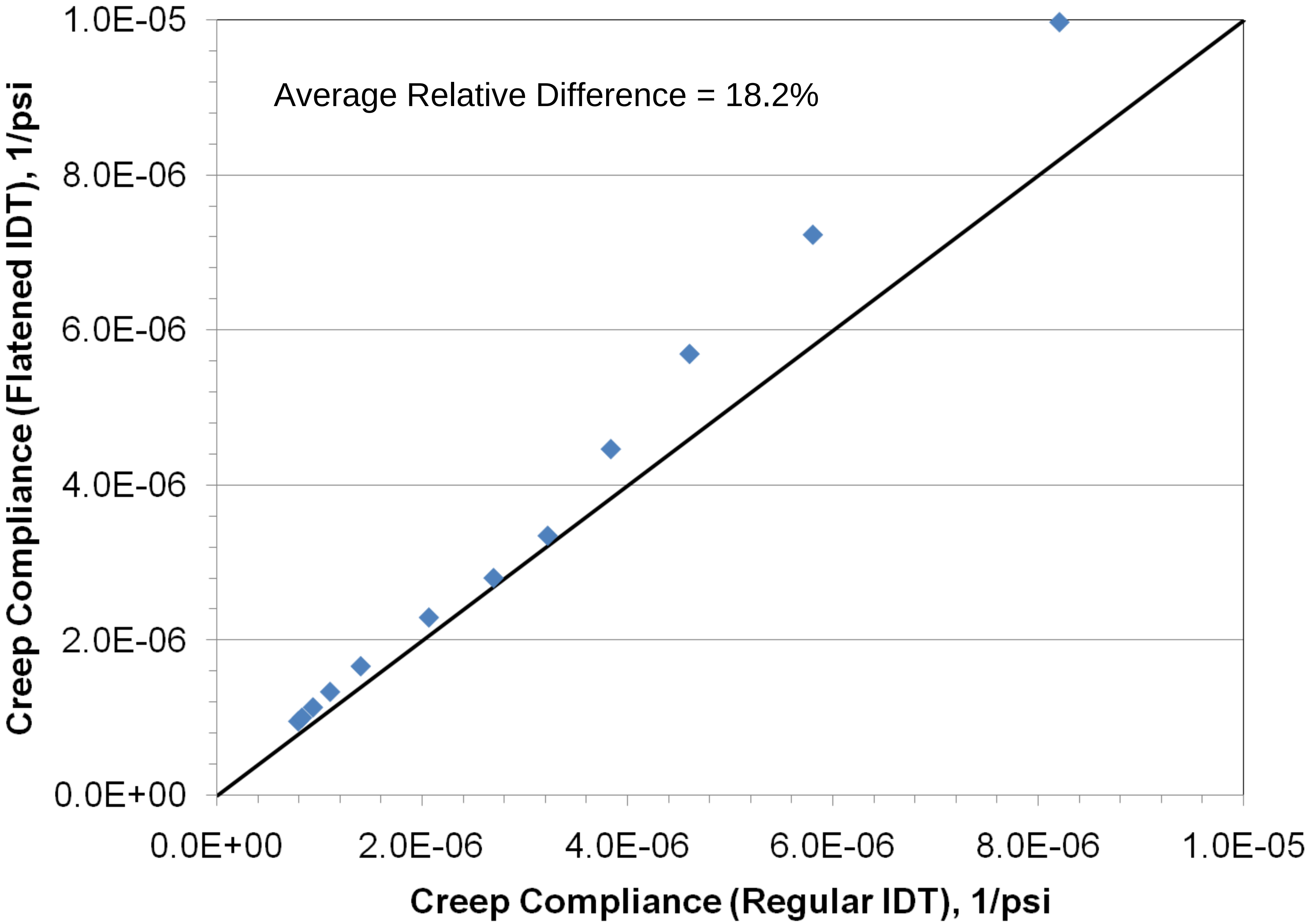
Average relative deviation = 14.8%
Creep Compliance (Flatened IDT), 1/psi
1.0E-05
8.0E-06
6.0E-06
4.0E-06
2.0E-06
0.0E+00
0.0E+00
2.0E-06
4.0E-06
6.0E-06
8.0E-06
1.0E-05
Creep Compliance (Regular IDT), 1/psi

Mix-40



Regular IDT
Flat IDT (alpha = 50-deg)
Average Relative Difference = 18.2%
Creep Compliance (1/GPa)
1.0E-04
8.0E-05
6.0E-05
4.0E-05
2.0E-05
0.0E+00
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05
1.0E+06
Time (sec)

Mix-40


Average Relative Difference = 18.2%
1.0E-05
8.0E-06
6.0E-06
4.0E-06
2.0E-06
0.0E+00
Creep Compliance (Flatened IDT), 1/psi
0.0E+00
2.0E-06
4.0E-06
6.0E-06
8.0E-06
1.0E-05
Creep Compliance (Regular IDT), 1/psi

Concluding Remarks

- Creep compliances for flattened IDT geometries were estimated using Hondros solution based method
- The predictions for flattened IDT were comparable with those determined for regular IDT (11 to 18% difference)
  - Greater difference for compliant mixtures
- The relative differences are within anticipated measurement and testing variability
- Further testing and analysis is currently underway.

Thank you for your attention!!