# Interlaboratory Variability of Slip Coefficient Testing of Organic Zinc Primers

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Robert Kogler – Rampart, LLC





## Big Deal, Who Cares……

Some organic zinc rich coatings no longer meet Class B performance

- Paint manufactures claim no change in formulation
- Paint manufactures blame the testing agencies
- Testing agencies blame the testing specification



"Welcome to my Nightmare on Elm Street" Dee McNeil – Sherwin-Williams

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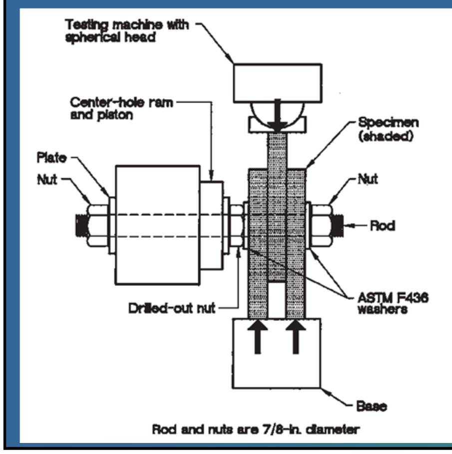
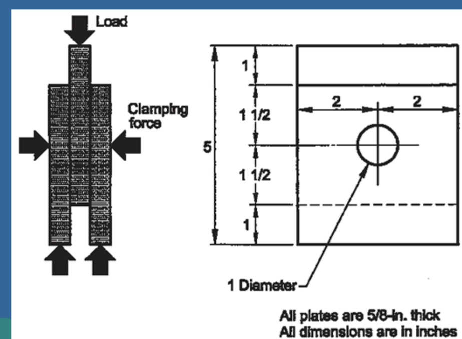
# Test Procedure

Appendix A, "Specification for Structural Joints Using High-Strength Bolts"

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# Test Matrix

1. Round Robin Testing – 4 labs
    - One federal research lab
    - One academic research lab
    - Two commercial testing labs
2. Five Organic Zinc-Rich Primers
    - PPG Amercoat 68HS (epoxy)
    - Sherwin-Williams Zinc-Clad III HS (epoxy)
    - Carboline Carbozinc 859 (epoxy)
    - Wasser MC 100 Zinc (moisture-cured urethane)
    - International Interzinc 315B (epoxy)
3. Two Coating Thicknesses
    - +1 and +2 mils over manufactures recommendations

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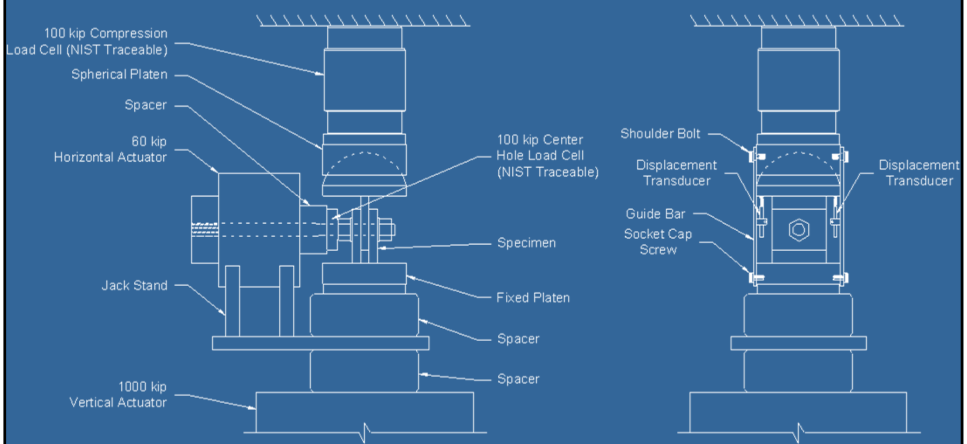
# Lab Setups



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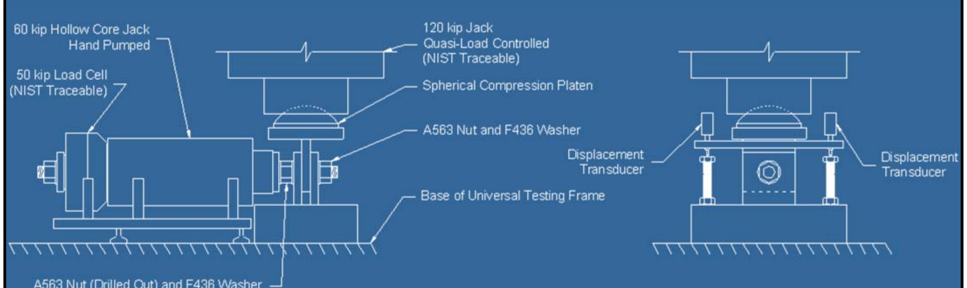


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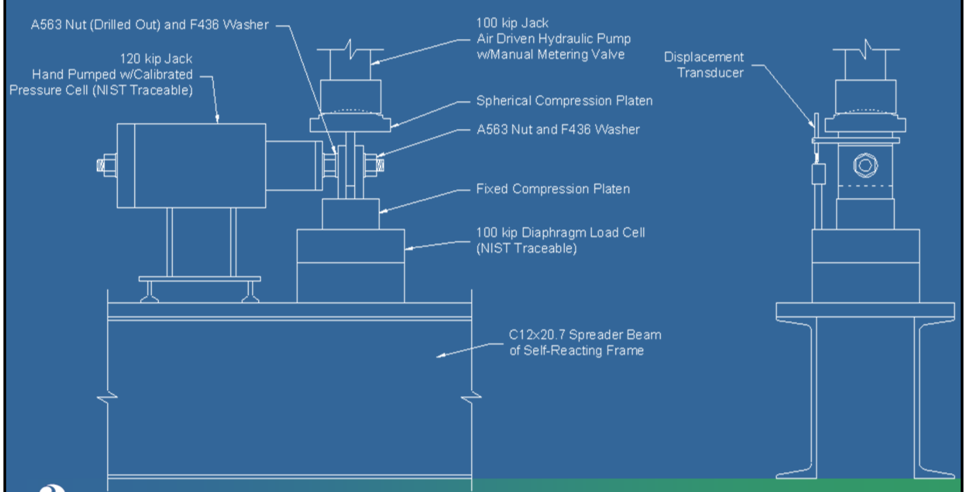


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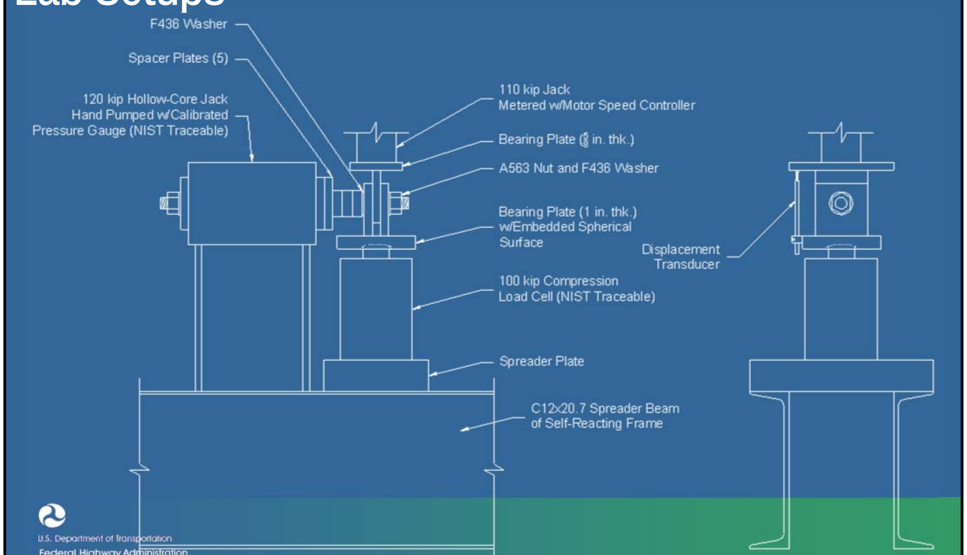
# Lab Setups

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# Results – "The Decoder Ring"

1. Labs 1, 2, 3, and 4

2. Coatings A, B, C, D, and E

3. Specimen follow format of "XY-Z"
   - "X" = letter of coating
   - "Y" = 1 or 2 based on coating thickness
   - "Z" = specimen number since five replicates tested
   - *Therefore, Coating B, +1 mils, specimen 3 is "B1-3"*

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# Results – All Slip Coefficients

| Lab | Specimen | A1 | A2 | B1 | B2 | C1 | C2 | D1 | D2 | E1 | E2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1 | 0.55 | 0.53 | 0.55 | 0.57 | 0.61 | 0.60 | 0.46 | 0.46 | 0.47 | 0.45 |
| | 2 | 0.54 | 0.48 | 0.54 | 0.55 | 0.61 | 0.62 | 0.48 | 0.34 | 0.44 | 0.45 |
| | 3 | 0.55 | 0.51 | 0.56 | 0.55 | 0.62 | 0.61 | 0.38 | 0.47 | 0.47 | 0.44 |
| | 4 | 0.53 | 0.54 | 0.53 | 0.56 | 0.63 | a | 0.46 | 0.45 | 0.43 | 0.47 |
| | 5 | 0.52 | 0.53 | 0.55 | 0.56 | 0.60 | 0.57 | 0.46 | 0.47 | 0.44 | 0.46 |
| **2** | 1 | 0.51 | 0.48 | 0.54 | 0.54 | 0.29 | 0.65 | 0.31 | 0.51 | 0.47 | 0.35 |
| | 2 | 0.306 | 0.43 | 0.54 | 0.74 | 0.60 | 0.63 | 0.50 | 0.27 | 0.47 | 0.18 |
| | 3 | 0.441 | 0.51 | 0.55 | 0.72 | 0.58 | 0.65 | 0.53 | 0.52 | 0.47 | 0.34 |
| | 4 | 0.392 | 0.53 | 0.54 | 0.54 | 0.47 | 0.66 | 0.38 | 0.63 | 0.25 | 0.44 |
| | 5 | 0.535 | 0.49 | 0.56 | 0.35 | 0.61 | 0.66 | 0.49 | 0.49 | 0.38 | 0.43 |
| **3** | 1 | 0.57 | 0.57 | 0.56 | 0.51 | 0.61 | 0.60 | 0.51 | 0.53 | 0.40 | 0.37 |
| | 2 | 0.56 | 0.55 | 0.56 | 0.55 | 0.61 | 0.59 | 0.51 | 0.52 | 0.38 | 0.41 |
| | 3 | 0.55 | 0.51 | 0.57 | 0.51 | 0.63 | 0.61 | 0.50 | 0.54 | 0.48 | 0.33 |
| | 4 | 0.57 | 0.53 | 0.59 | 0.52 | 0.60 | 0.61 | 0.51 | 0.54 | 0.41 | b |
| | 5 | 0.53 | 0.55 | 0.58 | 0.56 | 0.61 | 0.61 | 0.51 | 0.52 | 0.44 | b |
| **4** | 1 | | 0.54 | | | 0.59 | 0.57 | | | 0.45 | 0.46 |
| | 2 | | 0.53 | | | 0.58 | 0.51 | | | 0.48 | 0.46 |
| | 3 | | 0.53 | | | 0.60 | 0.59 | | | 0.46 | 0.40 |
| | 4 | | 0.54 | | | 0.59 | 0.60 | | | 0.42 | 0.43 |
| | 5 | | 0.55 | | | 0.59 | 0.61 | | | 0.46 | 0.44 |

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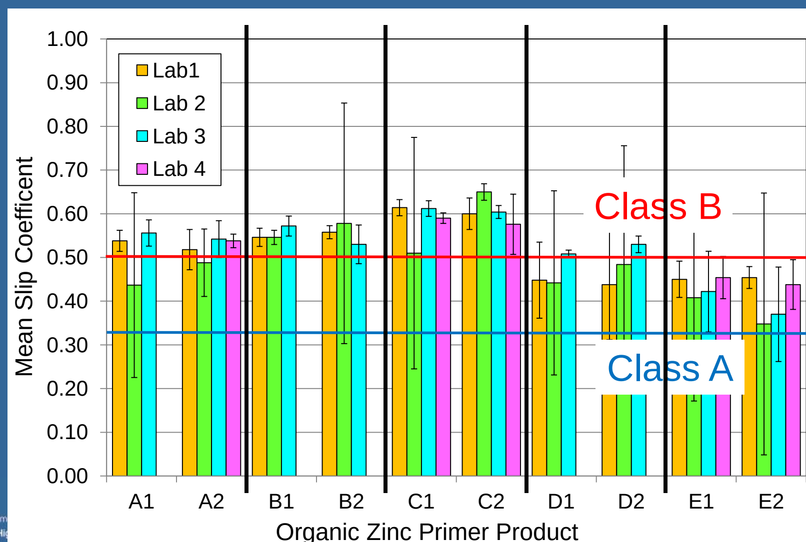
# Results –Averages and COV

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# Results – Just COVs

| Lab | A1 | A2 | B1 | B2 | C1 | C2 | D1 | D2 | E1 | E2 | AVG. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.024 | 0.046 | 0.021 | 0.015 | 0.019 | 0.036 | 0.087 | 0.127 | 0.042 | 0.025 | **0.044** |
| 2 | 0.211 | 0.077 | 0.016 | 0.275 | 0.265 | 0.019 | 0.211 | 0.272 | 0.237 | 0.300 | **0.188** |
| 3 | 0.030 | 0.042 | 0.023 | 0.044 | 0.018 | 0.015 | 0.009 | 0.019 | 0.092 | 0.108 | **0.040** |
| 4 | | 0.016 | | | 0.012 | 0.069 | | | 0.048 | 0.057 | **0.040** |

*There is something different about Lab 2, but what?*

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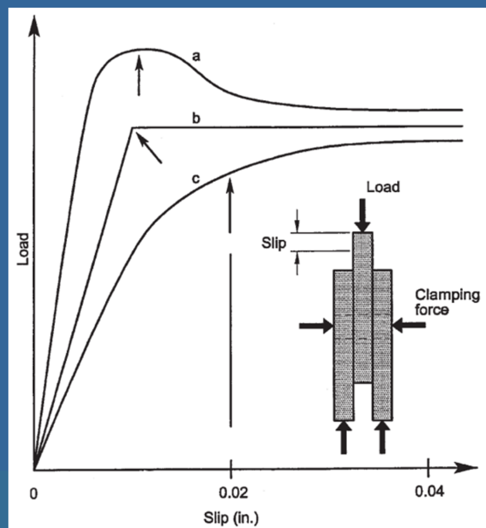
## Results – Failure Definition (RCSC)

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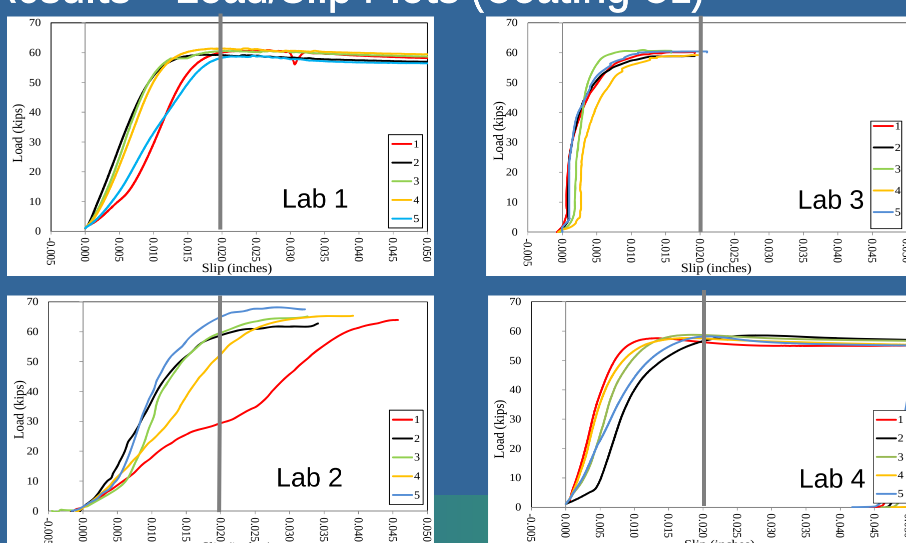
## Results – Load/Slip Plots (Coating C1)



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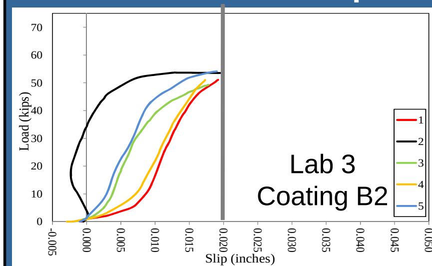
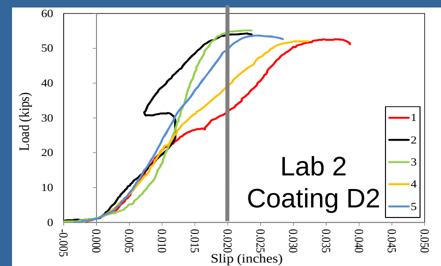
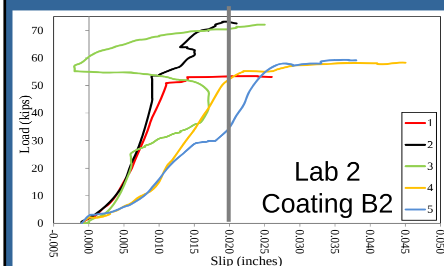
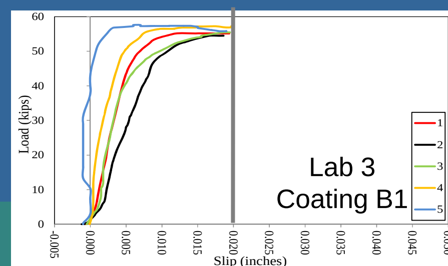
# Results – Load/Slip Plots, Other Oddities

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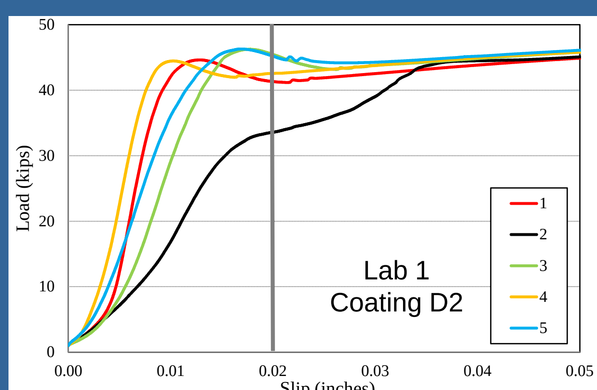
# Results – Load/Slip Plots, Other Oddities

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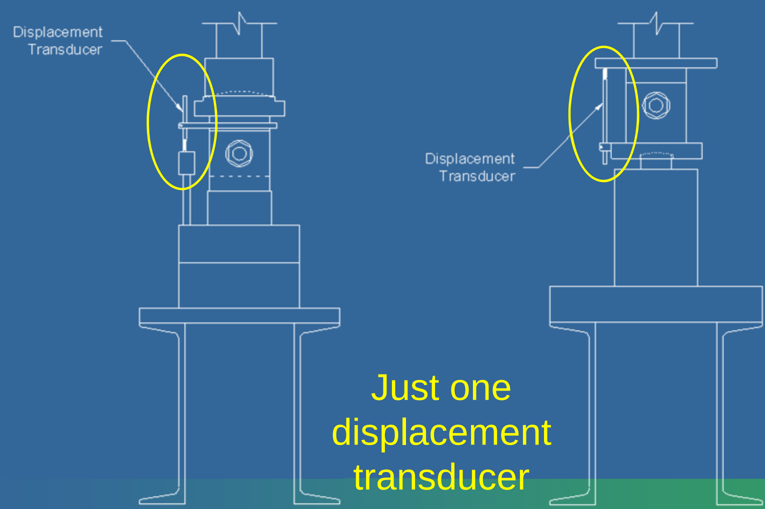
## Revisit the Loading Systems (Labs 2 and 3)




Just one displacement transducer

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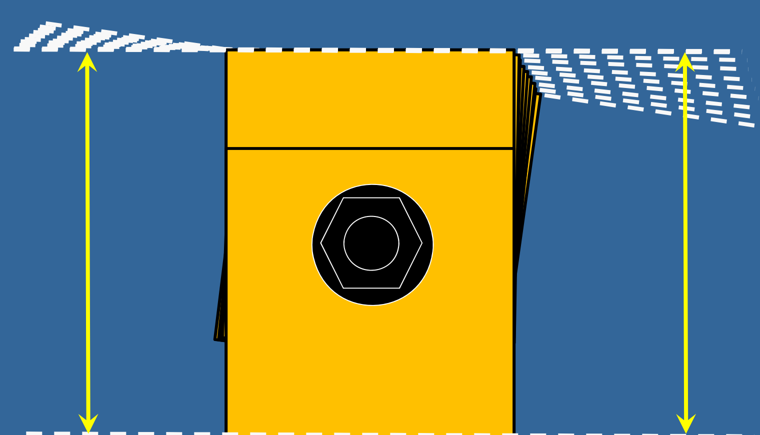
## Sensitivity of One LVDT



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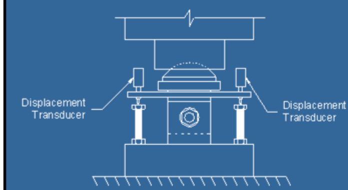
## Consequence of One Displacement Transducer

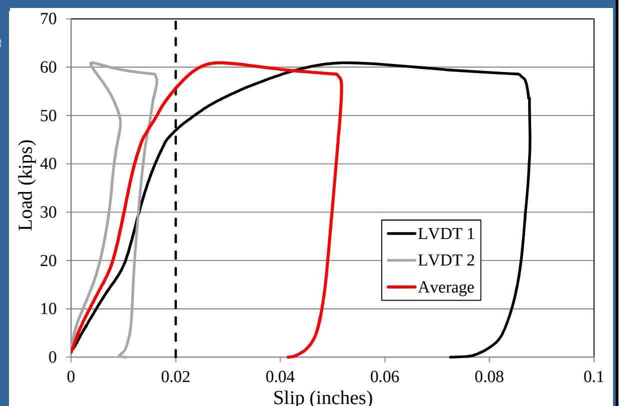



If just one LVDT was used, failure would be:

46.9 kips for LVDT 1 ($K_s$ = 0.48)

60.9 kips for LVDT 2 ($K_s$ = 0.62)

55.7 kips for Average($K_s$ = 0.57)




Specimen C2-1

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## Other Observations

1) Two labs took about 2.5-3 hours to run five samples, two labs took about 90 minutes to run five samples

*Noted labs that ran the five tests in ~90 minutes, spent less time aligning specimens*

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# Other Observations



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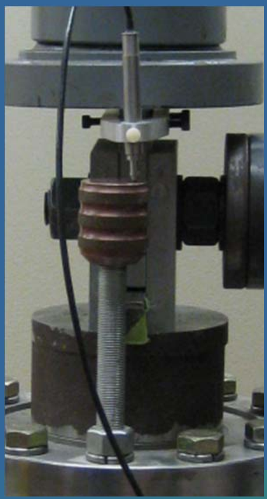
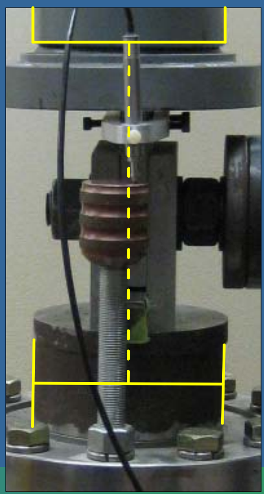
# Other Observations





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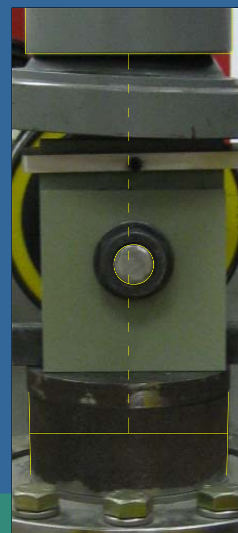
# Other Observations



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# RCSC Task Group to Revise Appendix A

11 April 2014 the RCSC Executive Committee approved the request to revise Appendix A

Task Group includes:

Karl Frank (Chair)
Todd Helwig
Joe Yura
Carly McGee
Justin Ocel
Sara Olthof

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# Highlights of Task Group Recommendations

1. Mandate the use of two displacement measuring devices
2. Increase clamping load to 50 kips (makes math easy)
3. Provide enhanced language about loading rates
4. Provide language about load train alignment and tolerances

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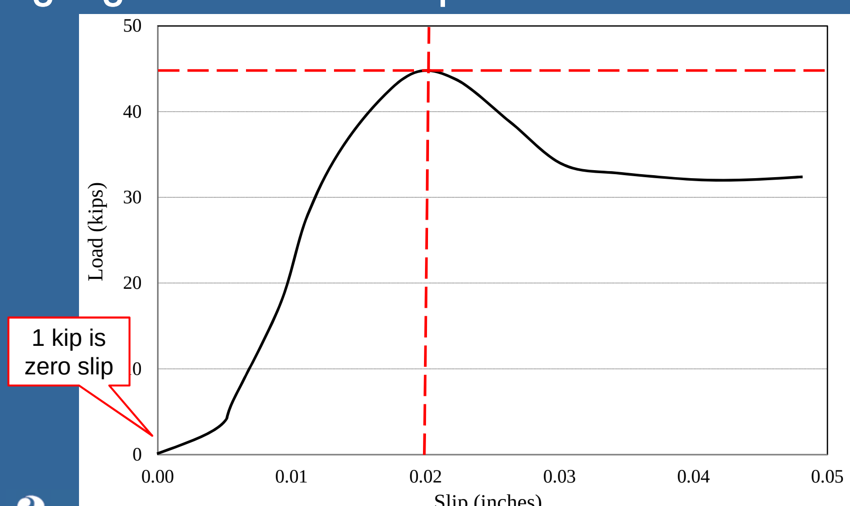
# Highlights of Task Group Recommendations

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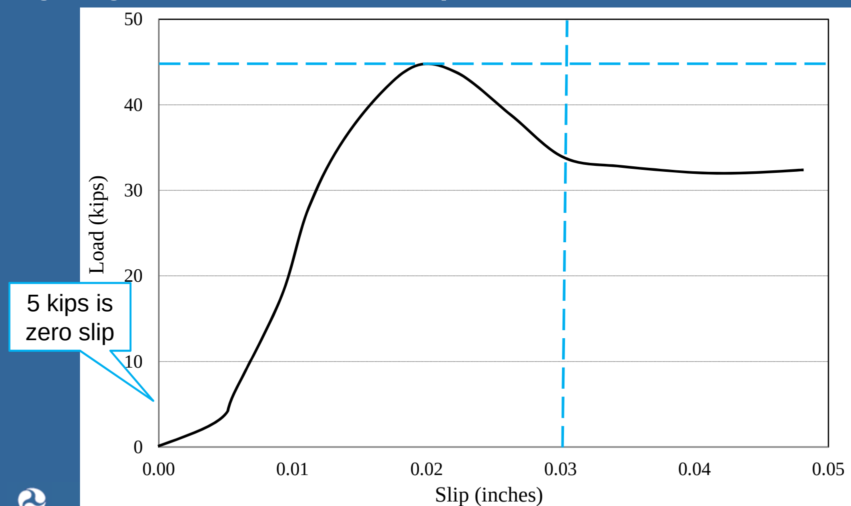
# Highlights of Task Group Recommendations



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# Highlights of Task Group Recommendations

5. Outlier analysis

| Specimen | Coefficient |
|---|---|
| 1 | 0.62 |
| 2 | 0.65 |
| 3 | 0.72 |
| 4 | 0.68 |
| 5 | [illegible] |
| Avg. | 0.60 |

New Avg. 0.67

# Highlights of Task Group Recommendations

5. Clarifications to tension creep test procedure

Creep Test Load= 2 x 0.8 $K_s$ $P_b$

Misunderstood, people were using minimum bolt tension

Clarified to be real bolt tension based on three calibrations



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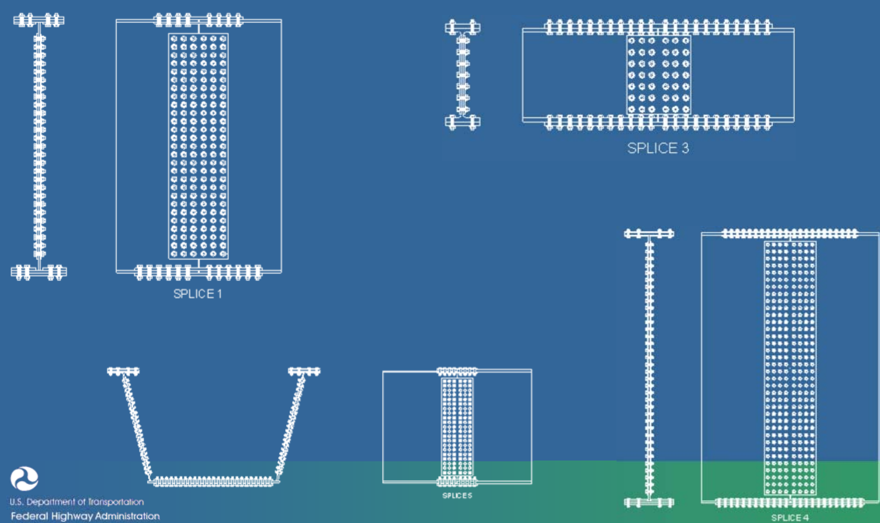
# Parametric Design Study

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# Parametric Design Study

| | |
|---|---|
| #1 | 90” deep I-girder, horizontally curved, field splice |
| #2 | 84” deep I-girder, straight bridge, field splice |
| #3 | W27x129, straight bridge, field splice |
| #4 | 132” deep I-girder, straight bridge, field splice |
| #5 | 71” deep tub girder, horizontally curved, field splice |
| #6 | 80” deep tub girder, horizontally curved, field splice |
| #7 | WF36x160, straight, cover plate retrofit |
| #8 | W24x84 stringer, straight, field splice |
| #9 | 92” deep I-girder, horizontally curved, field splice |
| #10 | LRFR truss member rating |

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## Parametric Design Study

| | AASHTO Strength I Design Efficiency | | |
|---|---|---|---|
| | Web | Top Flange | Bottom Flange |
| #1 | 0.59 | 0.64 | 0.88 |
| #2 | 0.90 | 0.89 | 0.88 |
| #3 | 0.93 | 0.85 | 0.85 |
| #4 | 0.49 | 0.37 | 0.47 |
| #5 | 0.53 | 0.80 | 0.82 |
| #6 | 0.98 | 0.92 | 0.94 |
| #7 | | | 0.92 |
| #8 | 0.70 | 0.78 | 0.78 |
| #9 | 0.94 | 0.76 | 0.80 |

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## Parametric Design Study – Discussion Points

1. Eliminate Class B, all slip-critical designs use $\mu$=0.35
2. Small study from FHWA suggests only ~10% of designs would be affected. Still need to look deeper
3. AISC (i.e. Schlafly) should consider similar parametric design study for vertical construction

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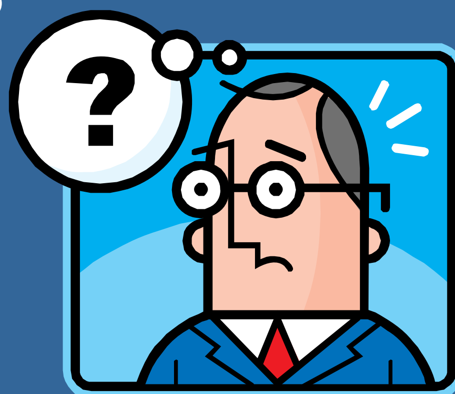
# Questions



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## High Priority Recommendations to RCSC

1. Impose tolerances for specimen and load train alignment
2. Try to encourage the use of digital DAQ in lieu of analog x-y plotters
3. Mandate the use of two displacement sensors, or at least show pictures of proper way to use one sensor and evaluate machine compliance

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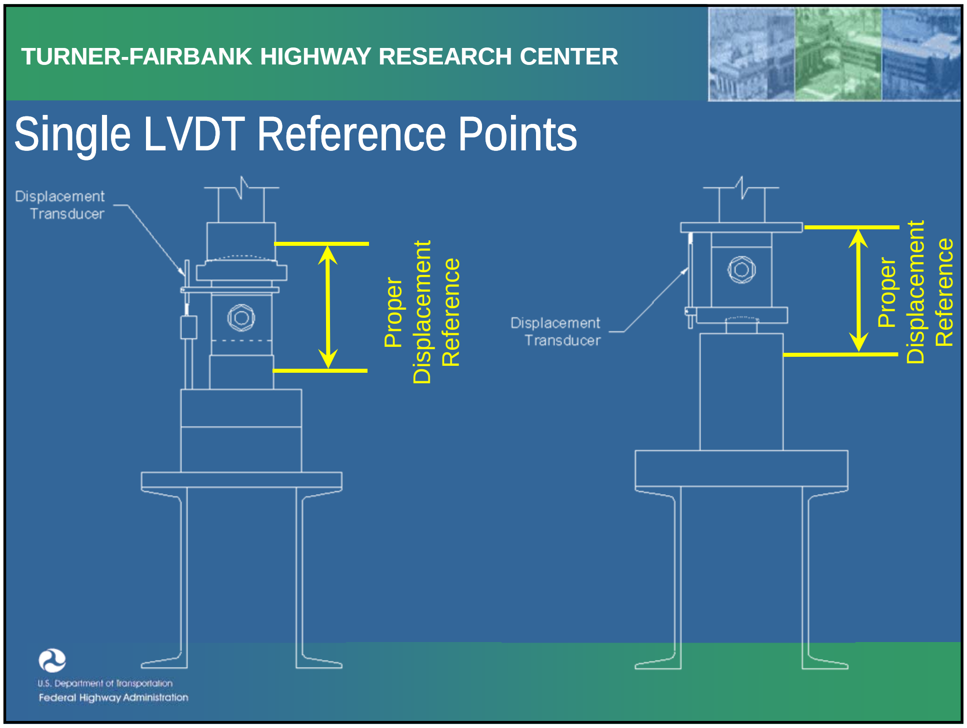

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Single LVDT Reference Points
Displacement Transducer
Proper Displacement Reference
Displacement Transducer
Proper Displacement Reference
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