Development of a Simple Procedure for Selecting Mixing and Compaction Temperatures

Association of Modified Asphalt Producers
Austin, TX
February 13, 2008

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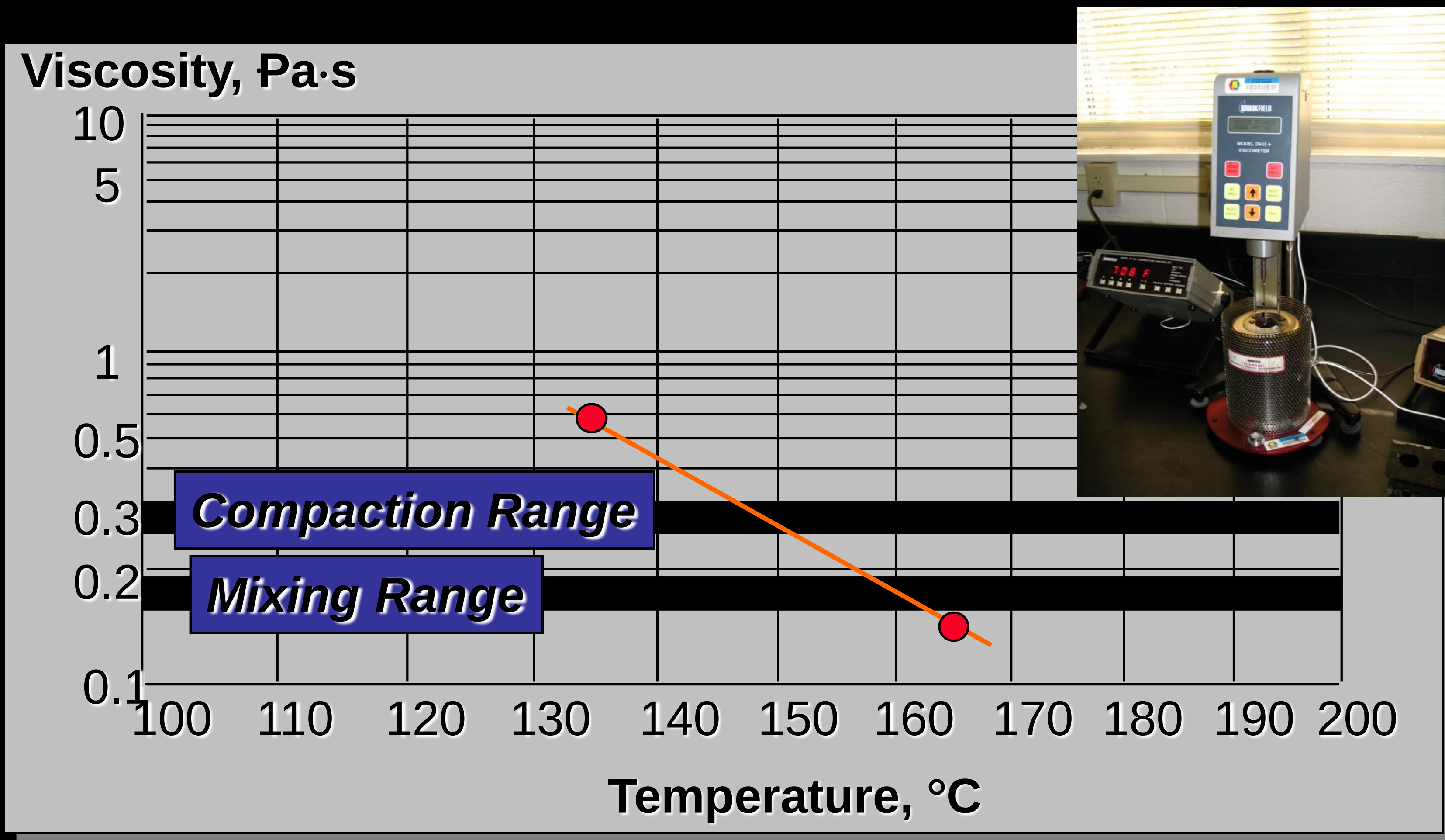
at Auburn University

NCHRP 9-39:
Mixing & Compaction Temperatures



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Background

- The Asphalt Institute equiviscous concept works well for unmodified, unfilled binders.
- For most modified binders, the equiviscous concept results in excessive mixing and compaction temperatures:
  - Emission concerns
  - Binder degradation concerns
- Most specifying agencies have relied on binder suppliers to recommend appropriate temperatures. However, no consensus exists on how that should be done.

Does temperature matter?

- The SGC compaction process is insensitive to binder stiffness because the compactor operates in a constant strain mode.
  - Temperature has almost negligible effect on volumetric properties.
  - However, mechanical tests on HMA are affected by mixing and compaction temperatures.

Different Views on Lab and Field Use of Mixing and Compaction Temperatures

- Some agencies set strict tolerances on discharge temperatures for plant mix using equiviscous temperatures.
- Some agencies consider equiviscous mixing and compaction temperatures applicable to the lab and use global temperature ranges in the field.

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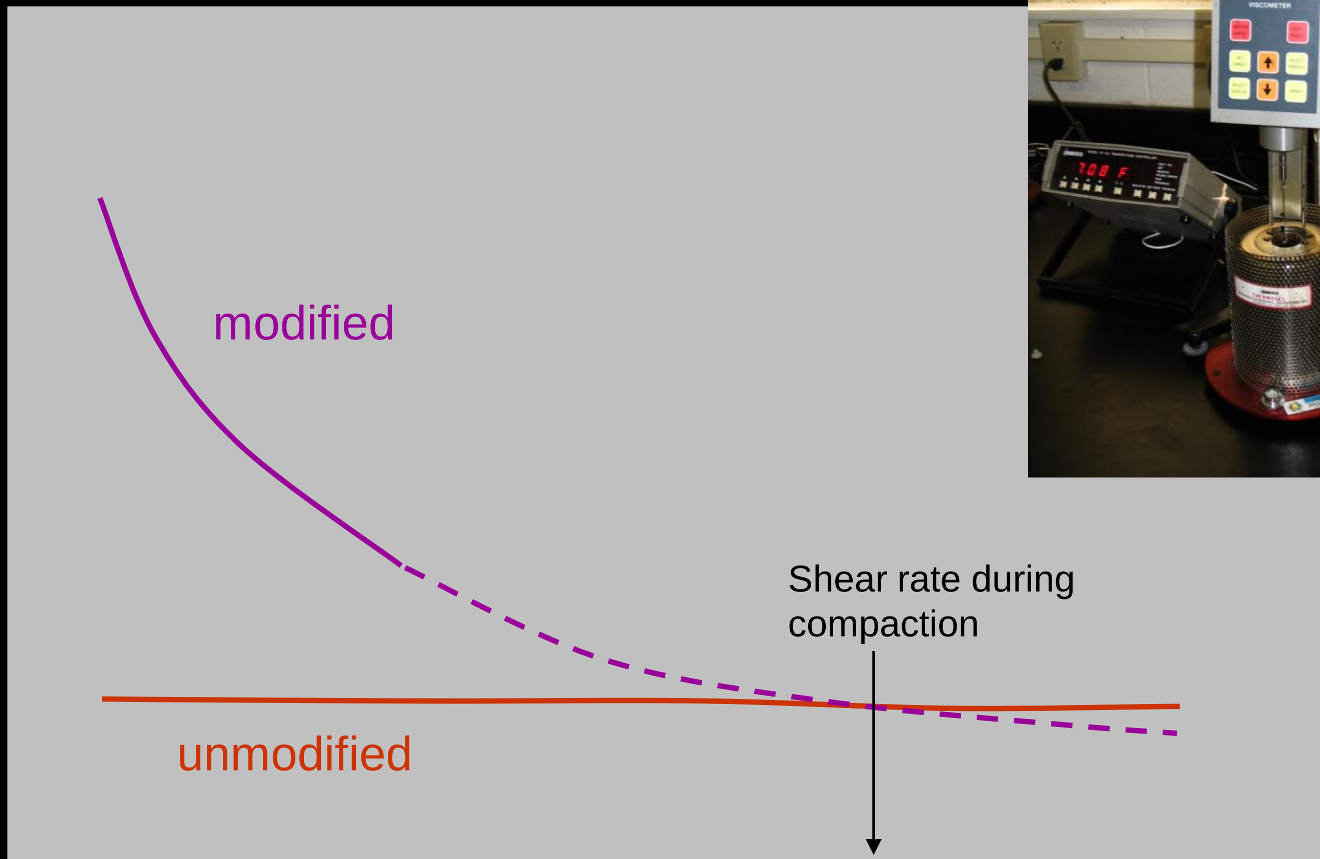
Candidate Methods for Determining Mixing & Compaction Temperatures

- High Shear Rate Viscosity (Yildirim)
- Steady Shear Flow (Reinke)
- Dynamic Shear Rheology (Casola)

High Shear Viscosity



Binder Viscosity

Shear Rate

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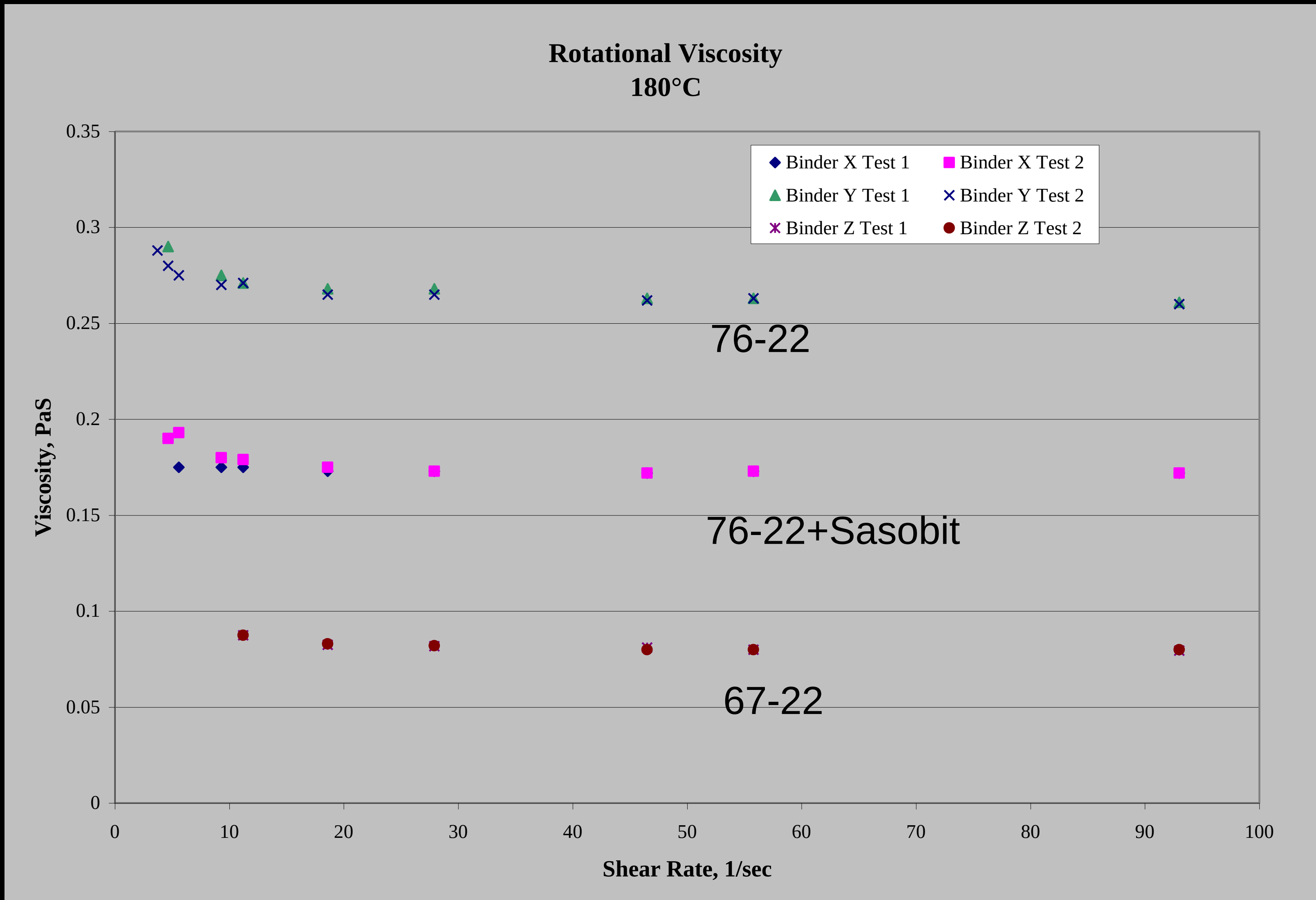
High Shear Viscosity



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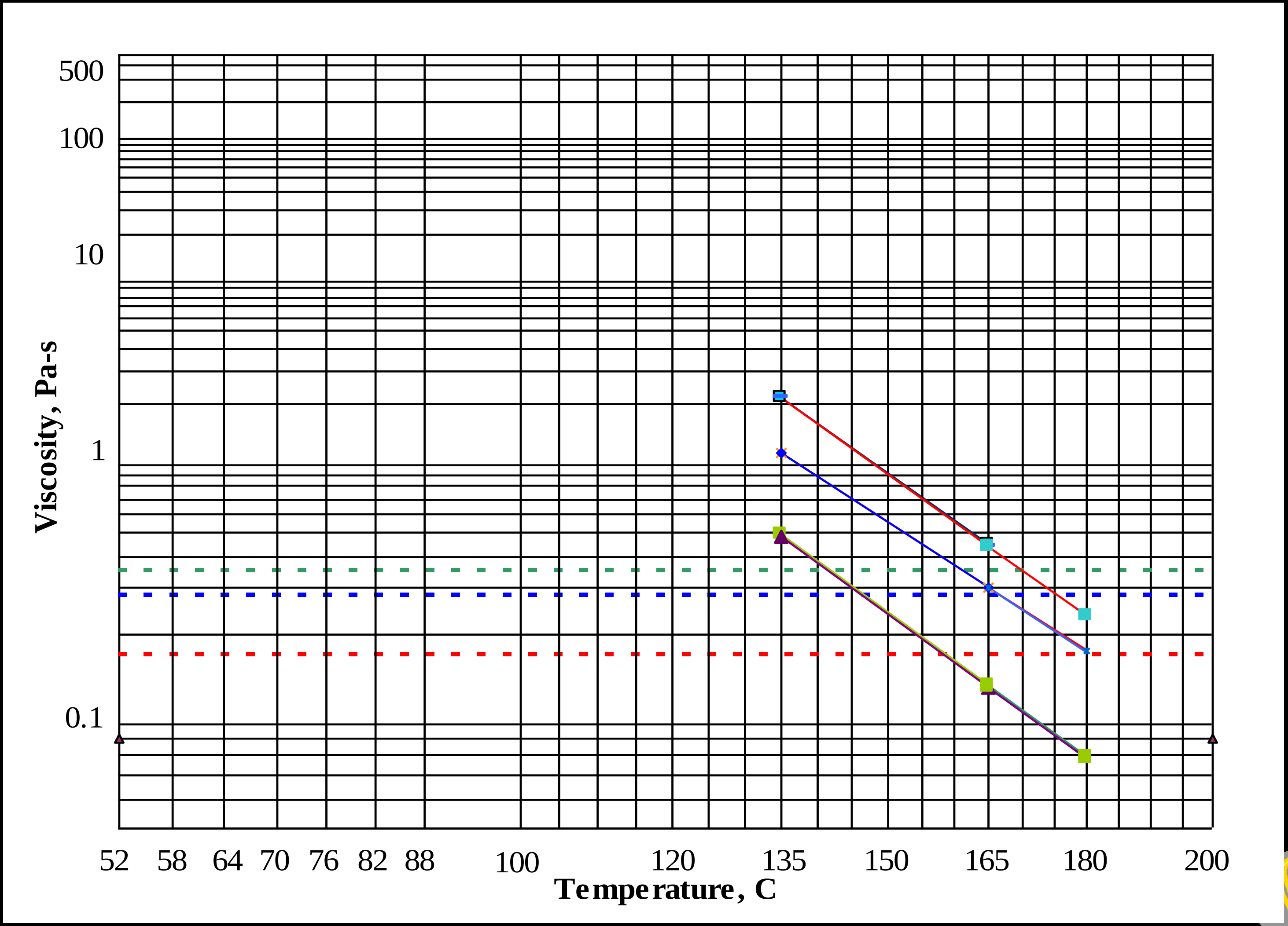
Extrapolated High Shear Viscosity



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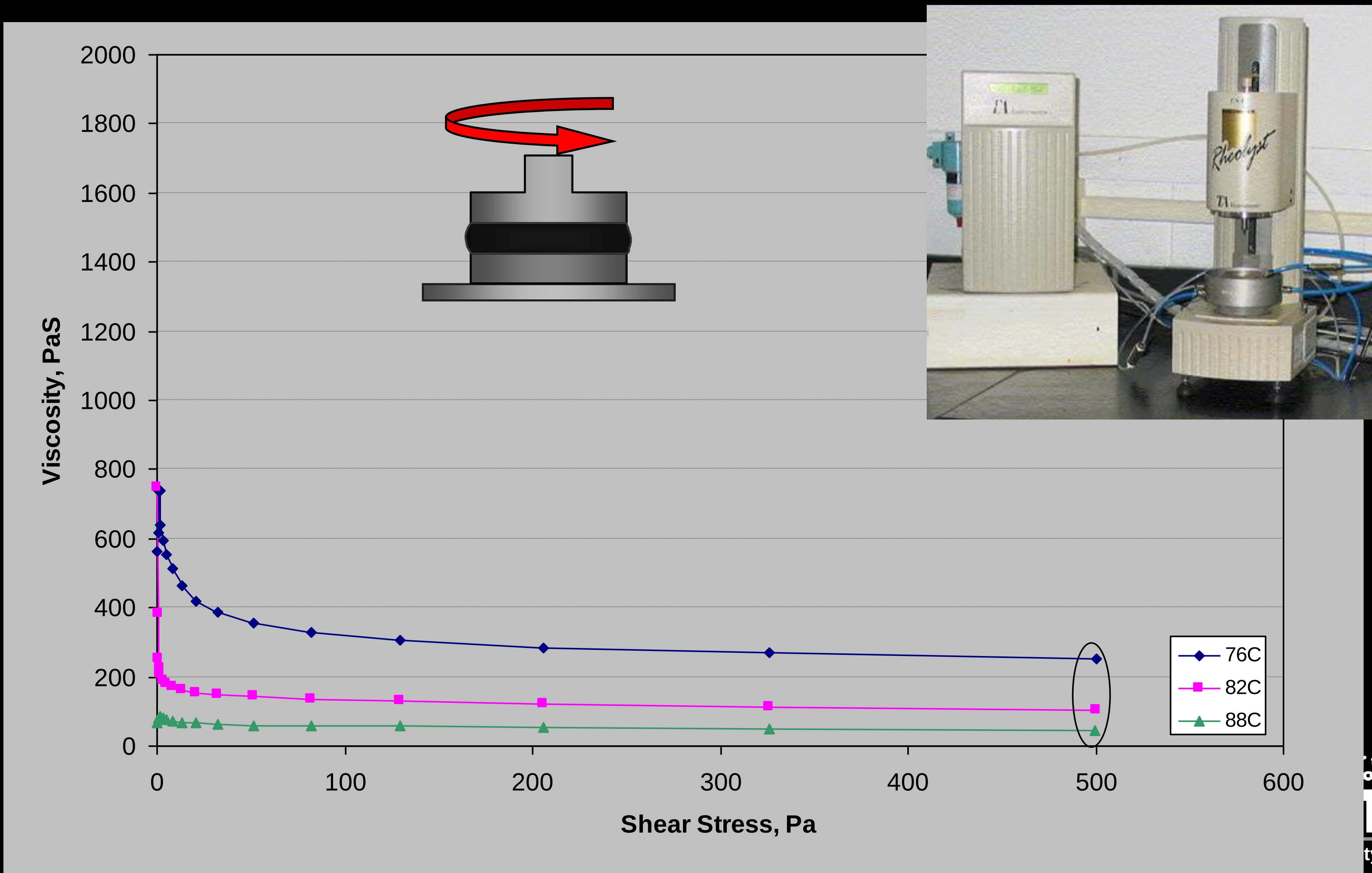
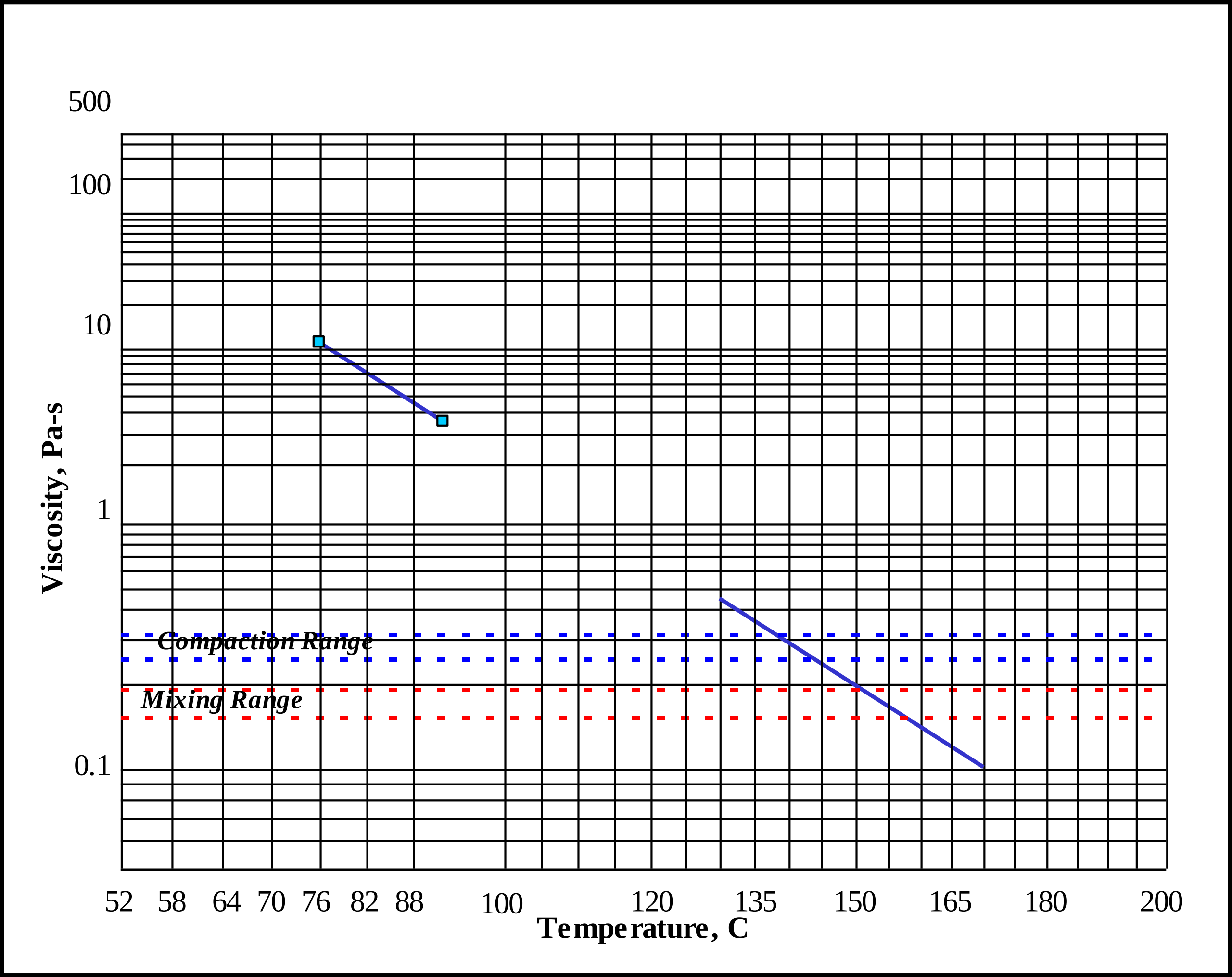
Steady Shear Flow Test



Extrapolation of SSF Viscosity



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Steady Shear Flow

- Mixing Temperature (ºF)

  Tm → 0.17 0.02 Pa·s

- Compaction Temperature (ºF)

  Tc → 0.35 0.03 Pa·s

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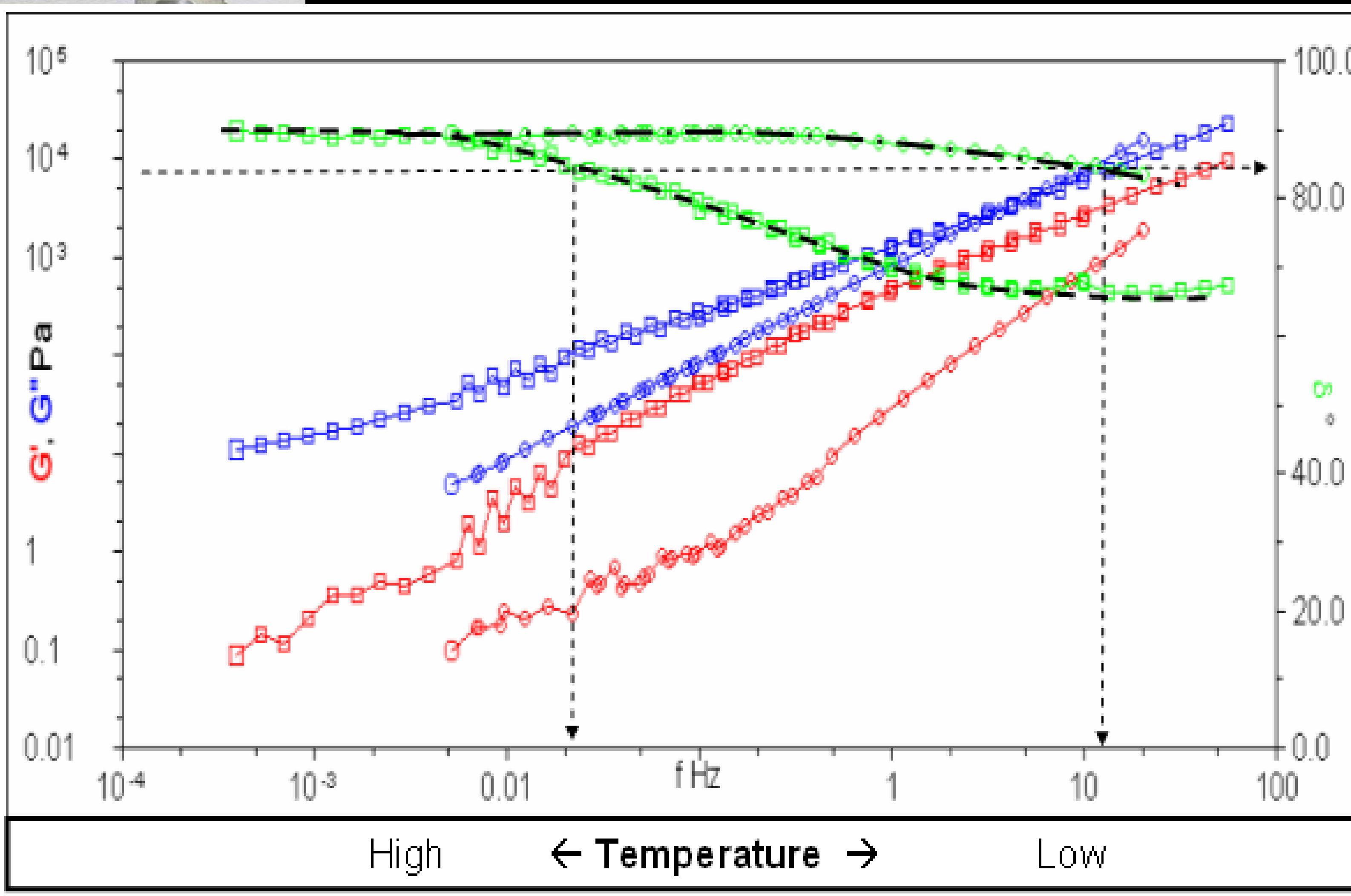
Casola Method – Phase Angle



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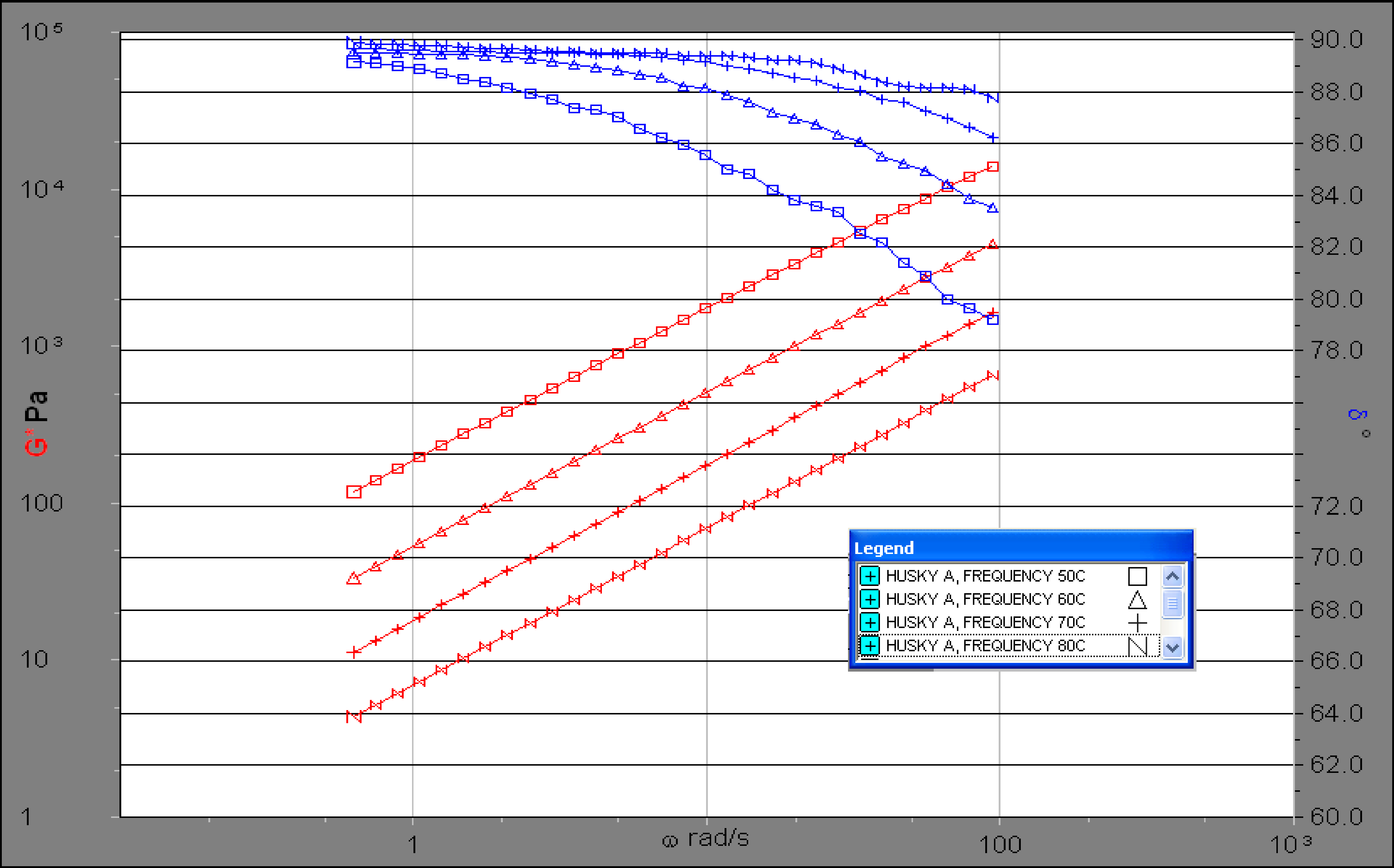
Casola Method

- Concept is based on the observation that visco-elastic behavior of binders at routine PG grading temperatures is a relative indicator of handling and mixing temperatures.
  - See EC 101
- The concept does not attempt to relate binder laboratory conditions to the infinite range of shear rates that exist in lab or field mixing and compaction.

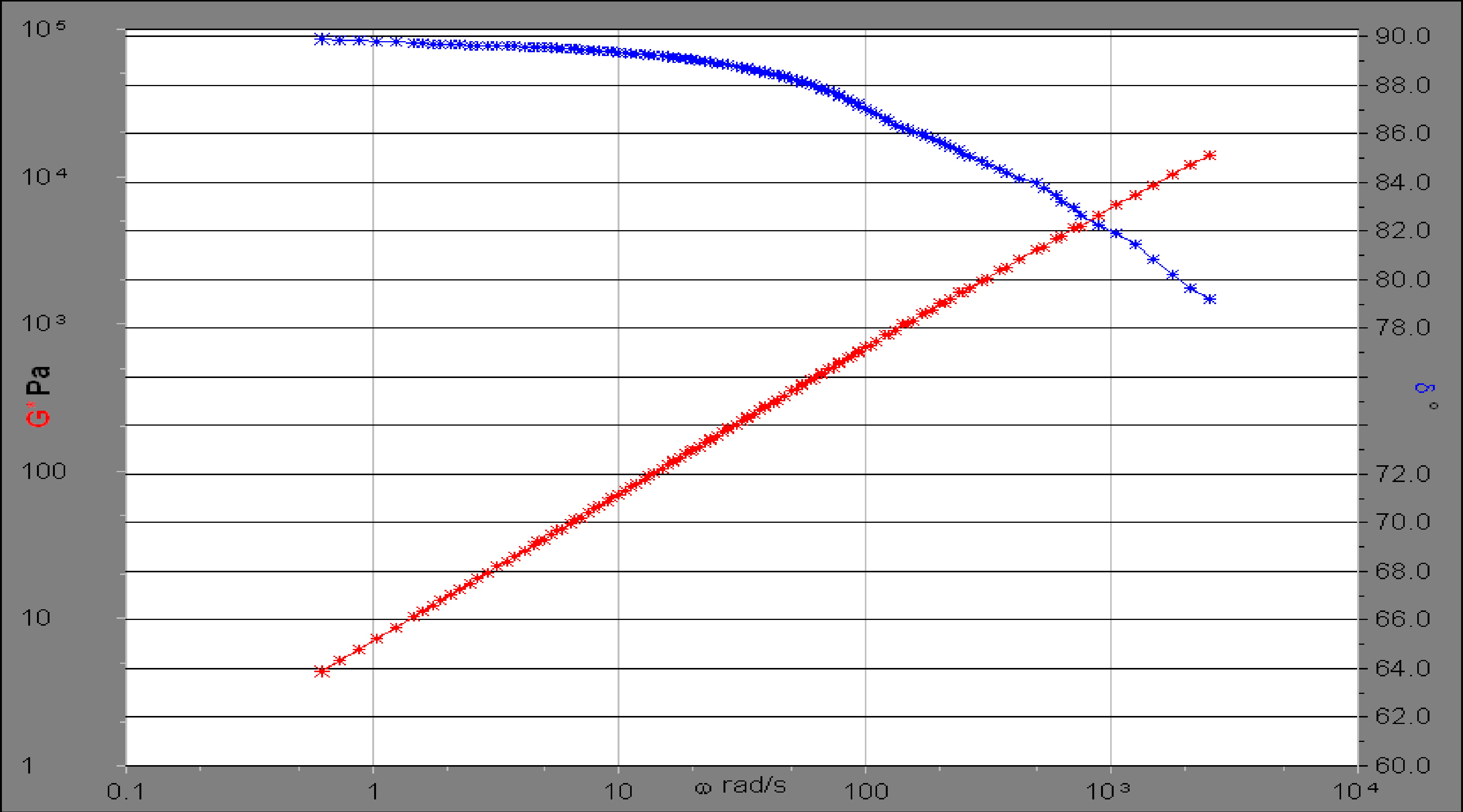
Casola Method

- Typical DSR sample preparation
- Frequency sweep at 3 to 5 temperatures
- Construct Phase Angle Master Curve
- Determine frequency where $\delta = 86^{\circ}$
- Calculate mixing and compaction temperatures using simple relationships established from regressions models

Frequency Sweep for a Binder 50, 60, 70 and 80ºC

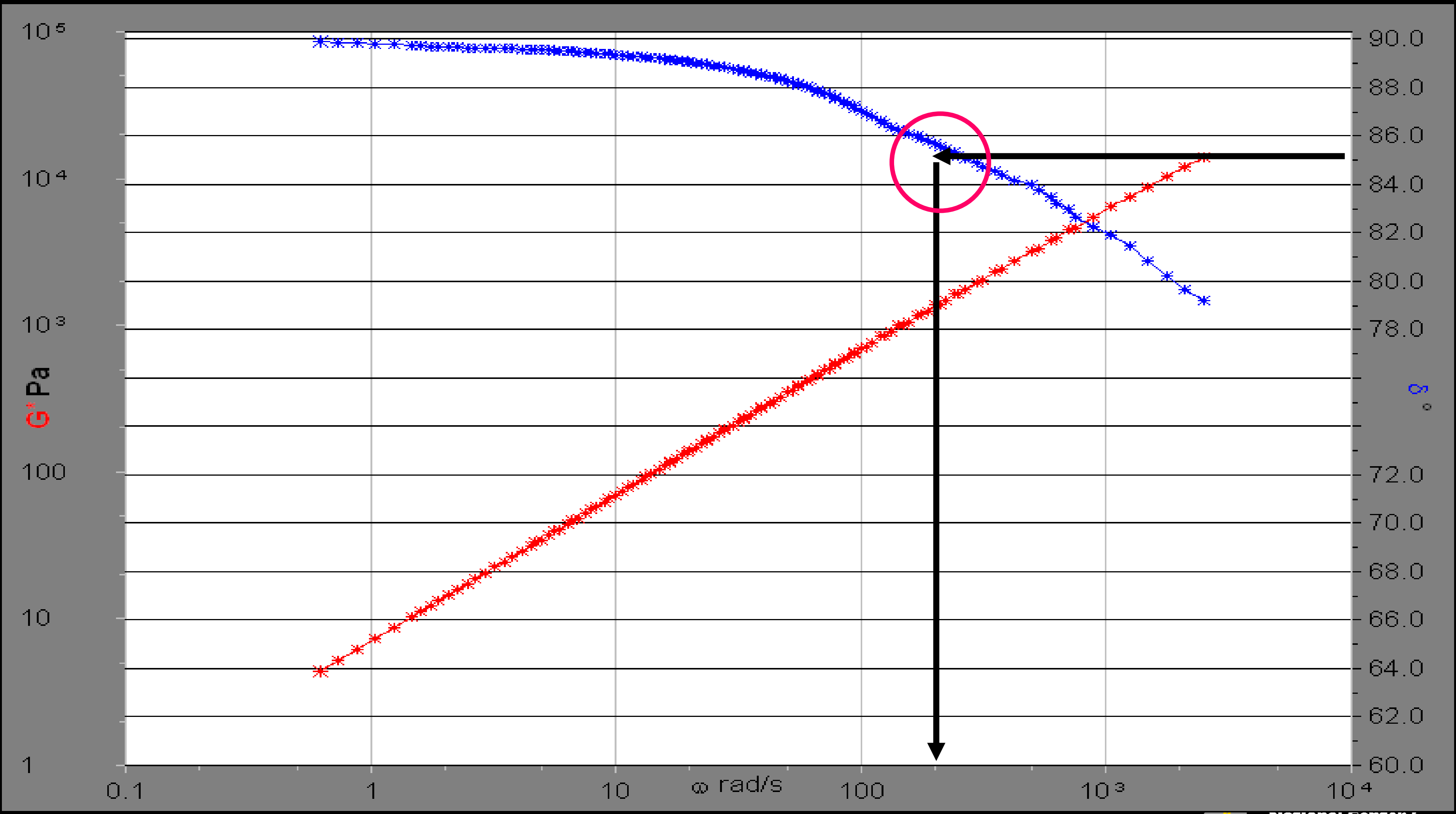


Sample A



10⁵
10⁴
10³
100
10
1
G* Pa
0.1
1
10
ω rad/s
100
10³
10⁴
90.0
88.0
86.0
84.0
82.0
80.0
78.0
72.0
70.0
68.0
66.0
64.0
62.0
60.0
δ °

Sample A



Freq = 158.45 Phase = 86.06 Temp = 80C

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Casola method

- Read frequency, ω, at which Phase Angle hits 86 degrees:
  - Mixing Temperature (ºF)

    $Tm = 310\omega^{-0.01}$

  - Compaction Temperature (ºF)

    $Tc = 287\omega^{-0.009}$

SSF method results

Binder ID	Modification	Actual Grade	Mixing Temperature (ºF)	Compaction Temperature (ºF)
G	SBS+PPA	PG 76-22	340	312
N	SBS	PG 82-22	337	311
H	SBS	PG 76-22	333	304
B	SBS	PG 64-34	325	295
C	SBS	PG 70-34	320	291
I	Air Blown	PG 70-28	316	289
F	None	PG 64-22	309	281
O	None	PG 64-28	309	280
M	F-T Wax+SBS	PG 82-16	296	275
E	Air Blown	PG 58-28	293	269
D	None	PG 58-28	289	262
J	None	PG 64-16	289	263
K	None	PG 64-10	280	257

Casola method results

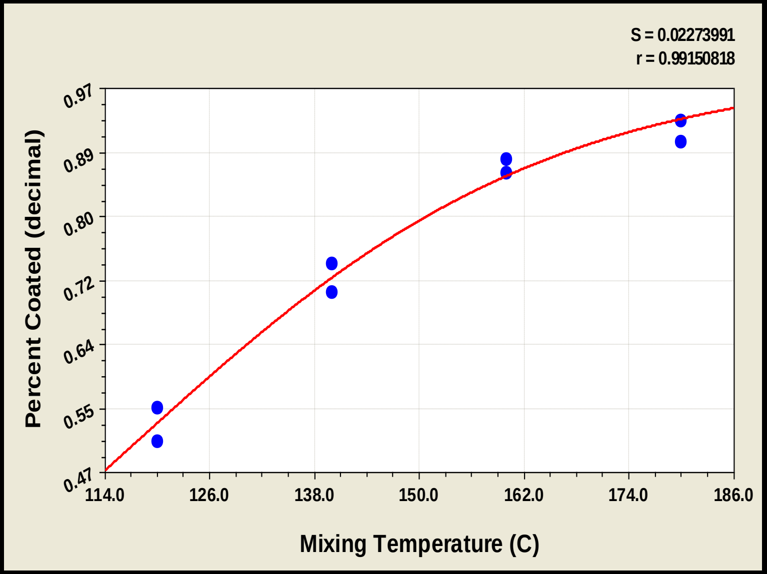
Binder ID	Modification	Actual Grade	Frequency at δ= 86º T = 80ºC	**Mixing Temperature (ºF)**	**Compaction Temperature (ºF)**
G	SBS+PPA	PG 76-22	0.03	**321**	**296**
N	SBS	PG 82-22	0.03	**321**	**296**
M	F-T Wax+SBS	PG 82-16	0.07	**318**	**294**
C	SBS	PG 70-34	0.21	**315**	**291**
H	SBS	PG 76-22	0.22	**315**	**291**
B	SBS	PG 64-34	1.10	**310**	**287**
I	Air Blown	PG 70-28	2.98	**307**	**284**
O	None	PG 64-28	21.12	**301**	**279**
E	Air Blown	PG 58-28	37.85	**299**	**278**
F	None	PG 64-22	75.00	**297**	**276**
D	None	PG 58-28	122.56	**296**	**275**
J	None	PG 64-16	580	**291**	**271**
K	None	PG 64-10	800	**290**	**270**

Research Approach

- Use candidate methods to predict mixing and compaction temperatures
- Use mix tests to validate mixing and compaction temperatures
- Perform regression analyses to correlate predicted mix and compaction temps with mix test results
- Check reasonableness
- Determine temperature limits that cause binder degradation and emissions problems

Mix Coating Tests

- Lab Pugmill Mixer and Bucket Mixer to simulate Batch Plant and Drum Plant Mixing
- Mix binders with a standard aggregate blend at four temperatures for a set time
- Rate aggregate coating percentage using Ross count



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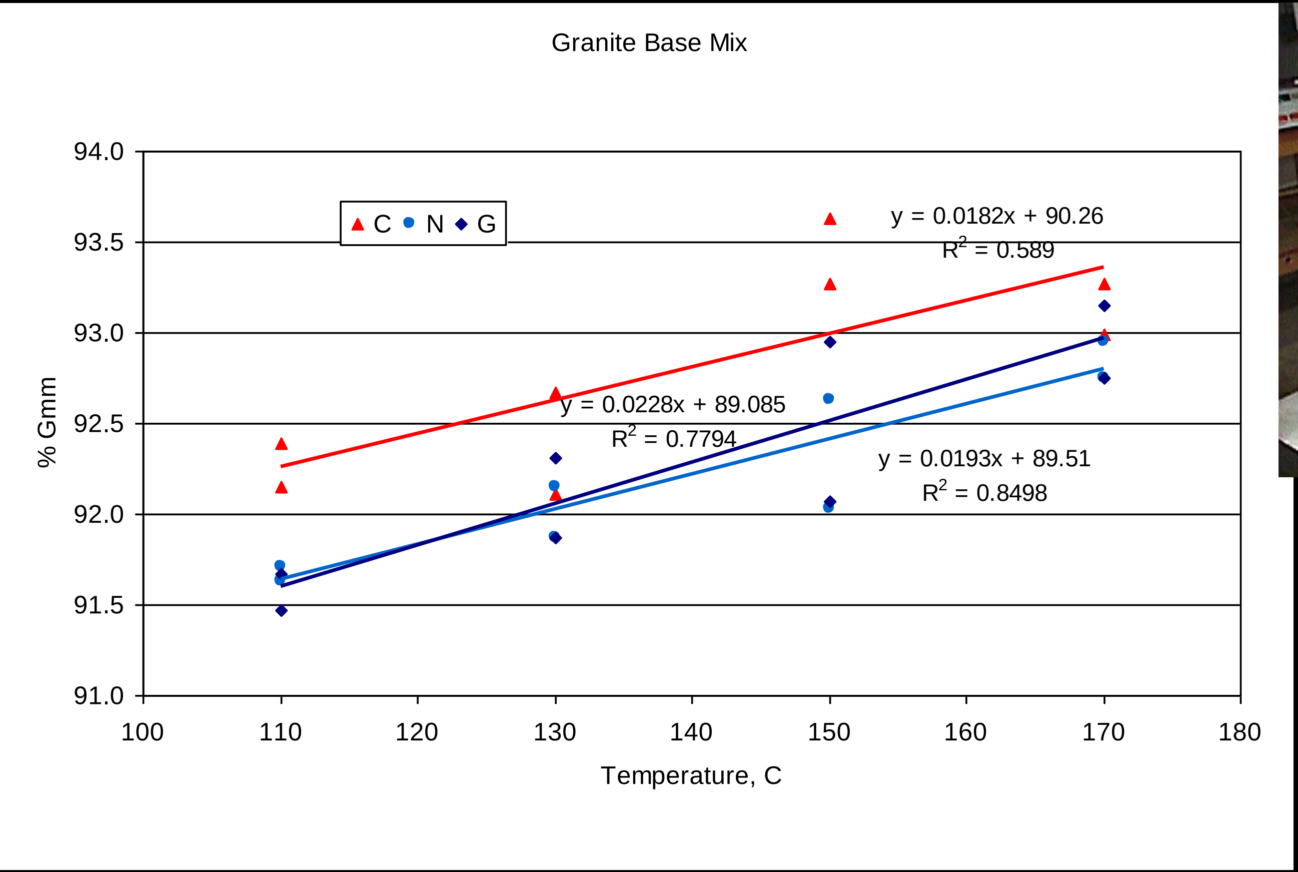
Mix Compactability

- Four compaction temperatures
- Used 25 gyrations to amplify effect of binder stiffness



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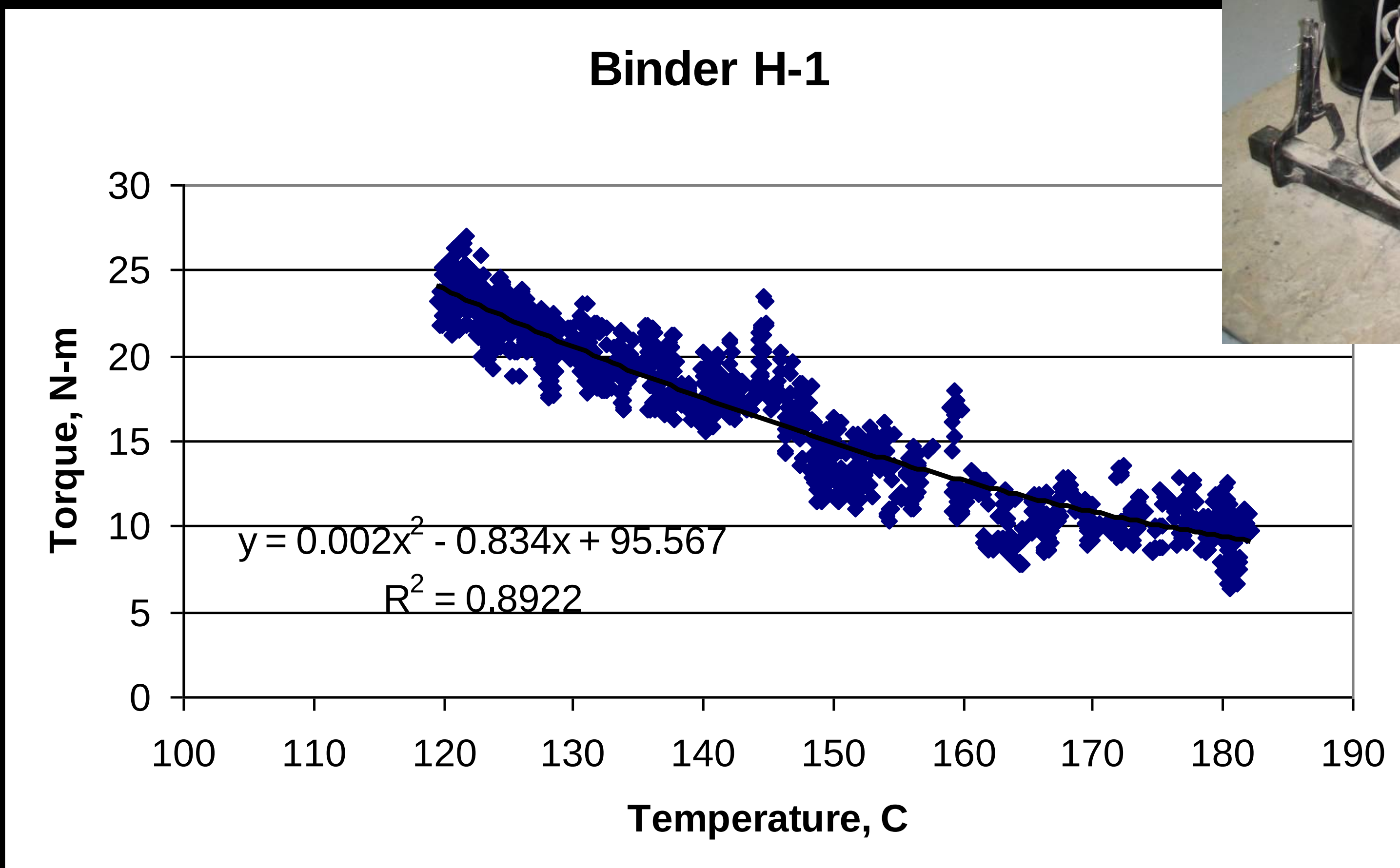
Mix Workability



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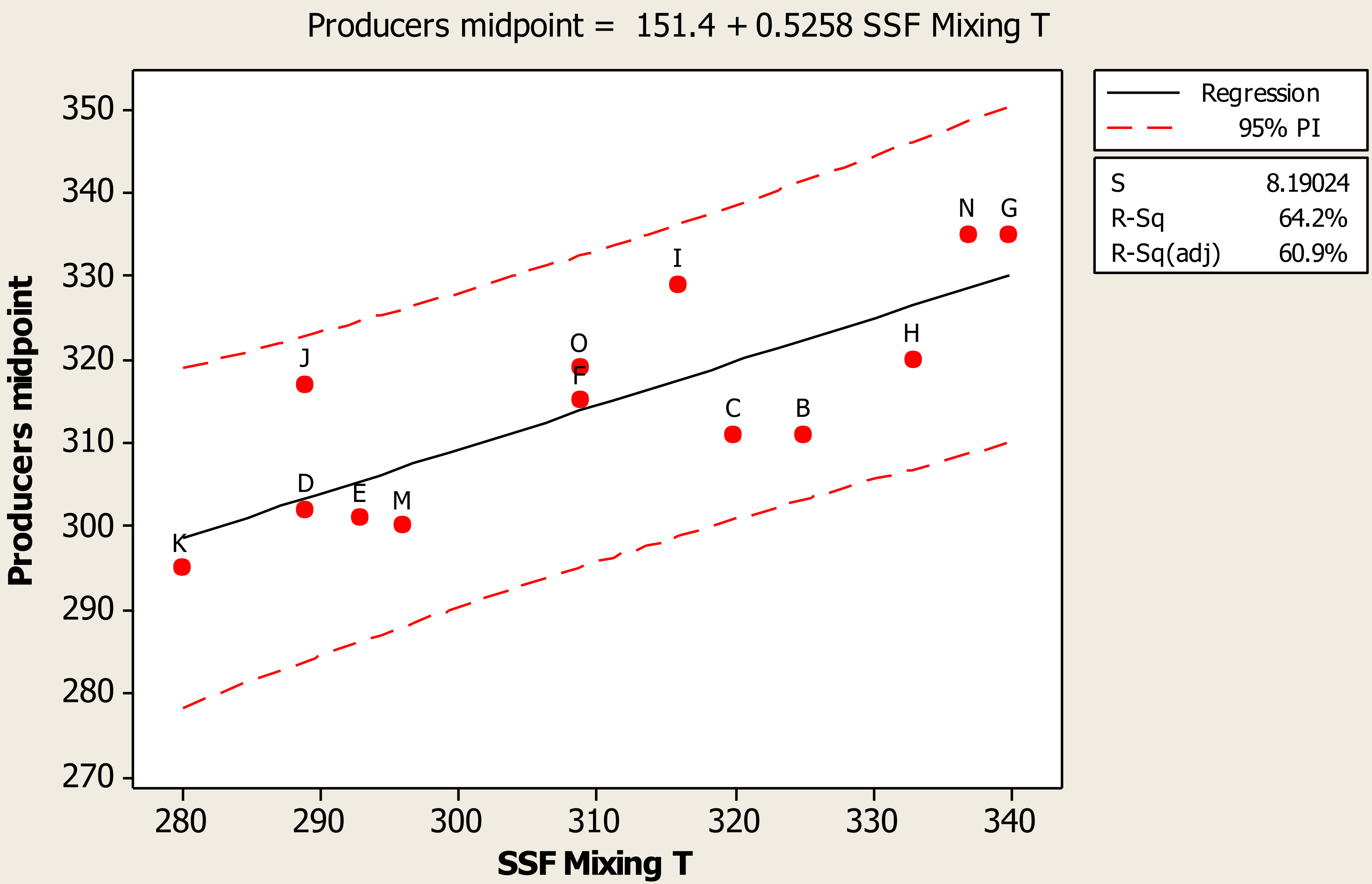
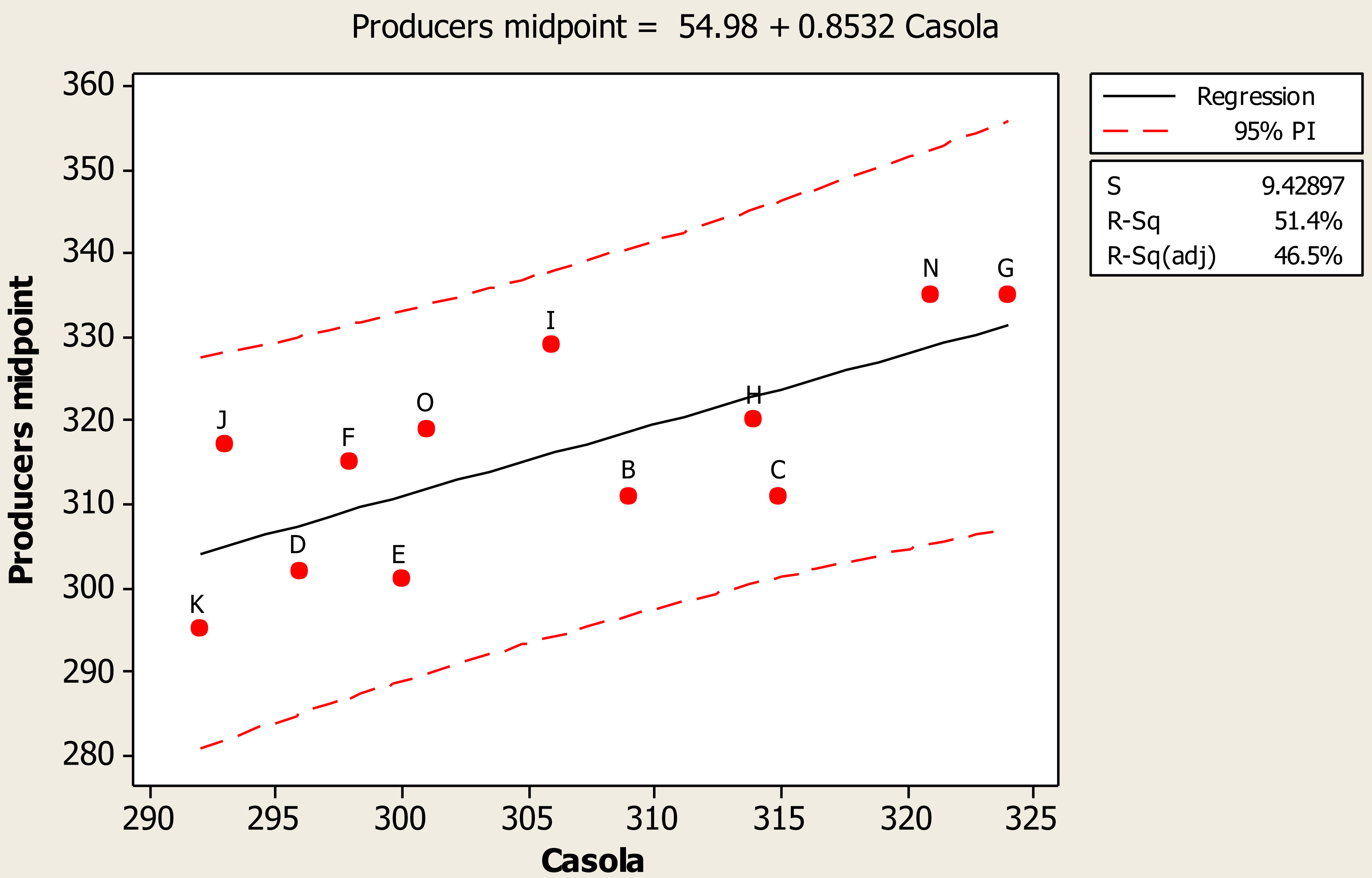
Correlation Analyses: Regressions between Results of Candidate Methods to Mixture Tests

Comparisons to Binder Producers’ Recommended Midpoints for Mixing

Steady Shear Flow method



Casola method



Comparisons to Lab Mixer Coating Test Results

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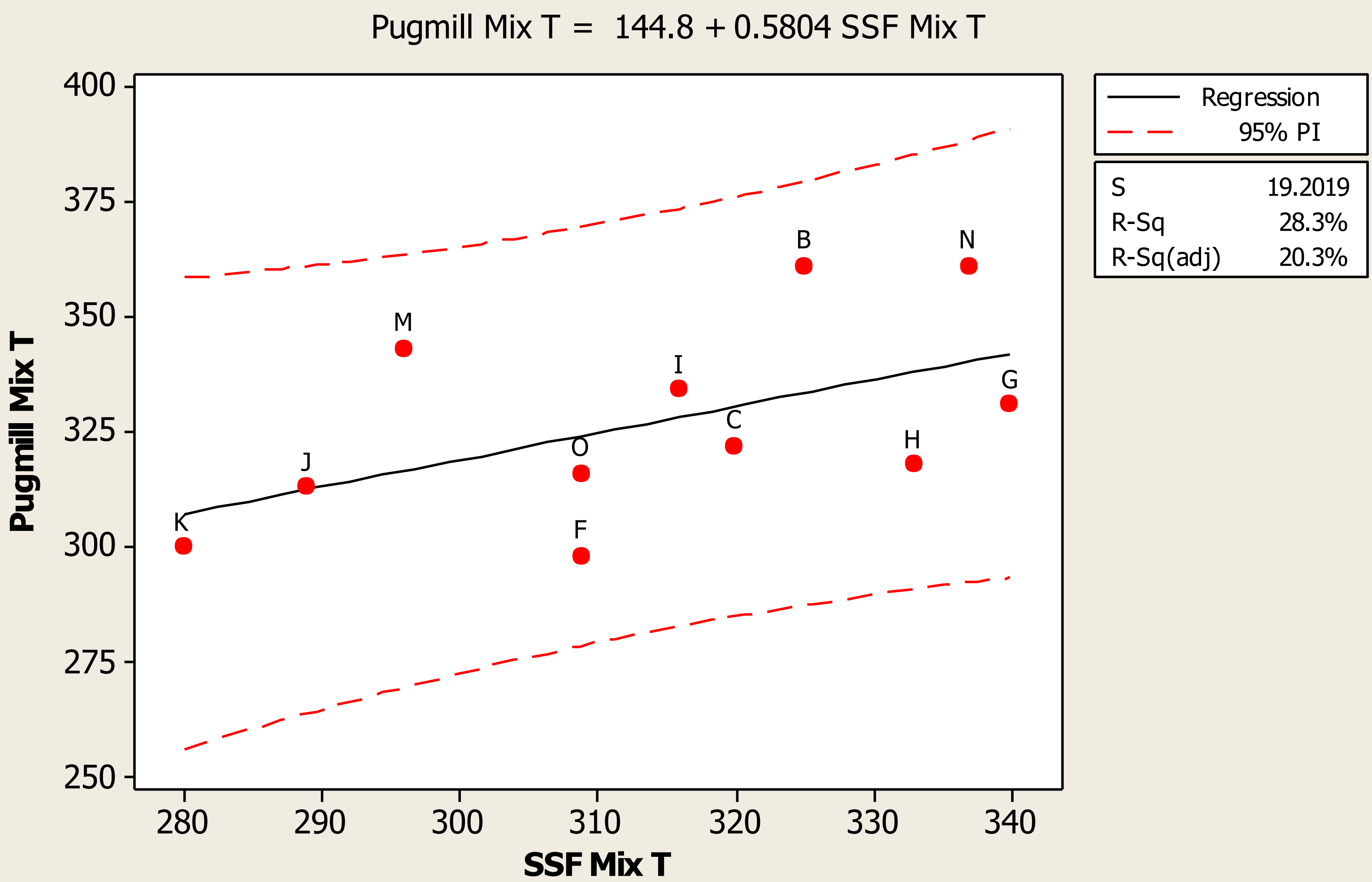
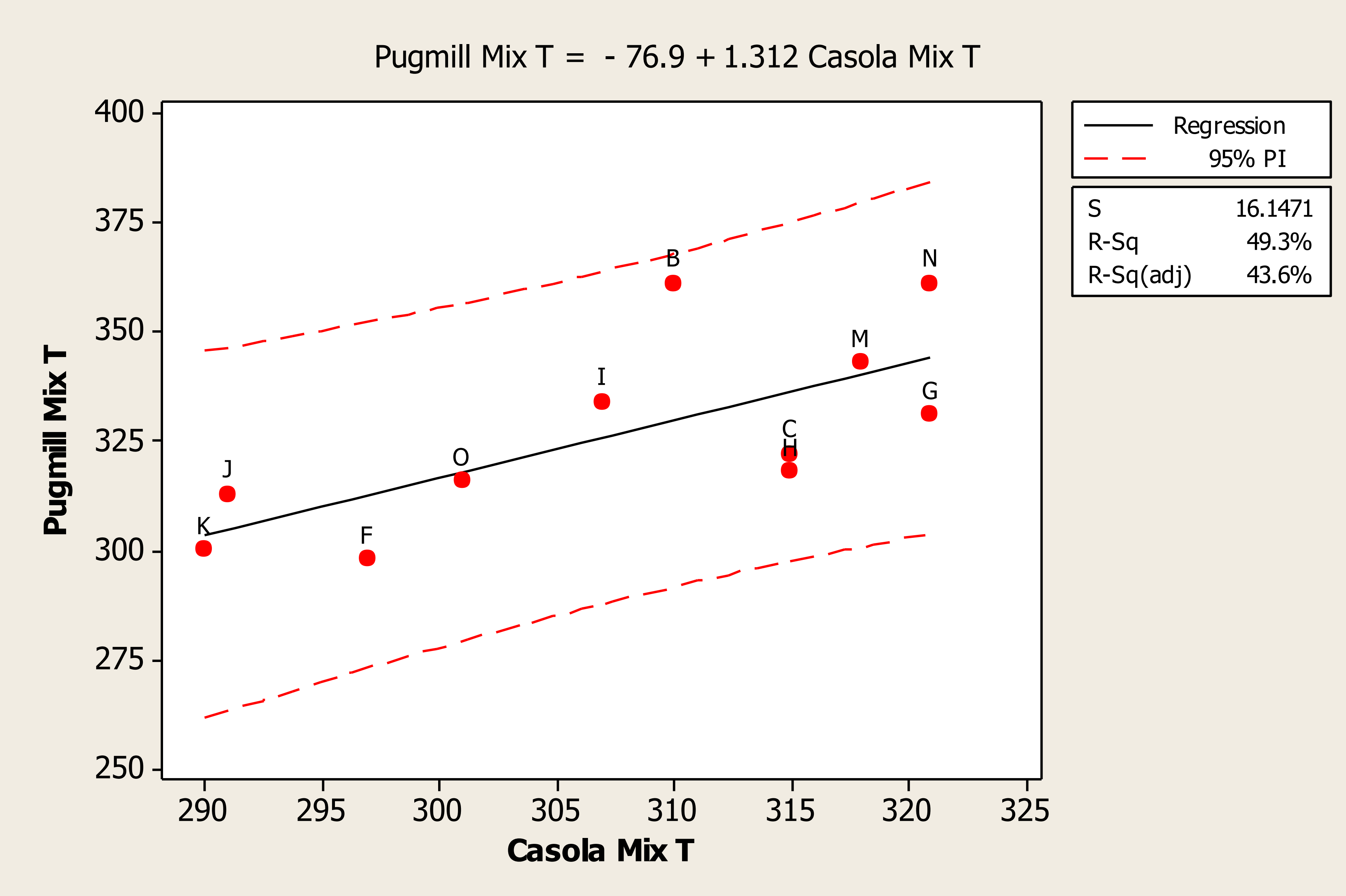
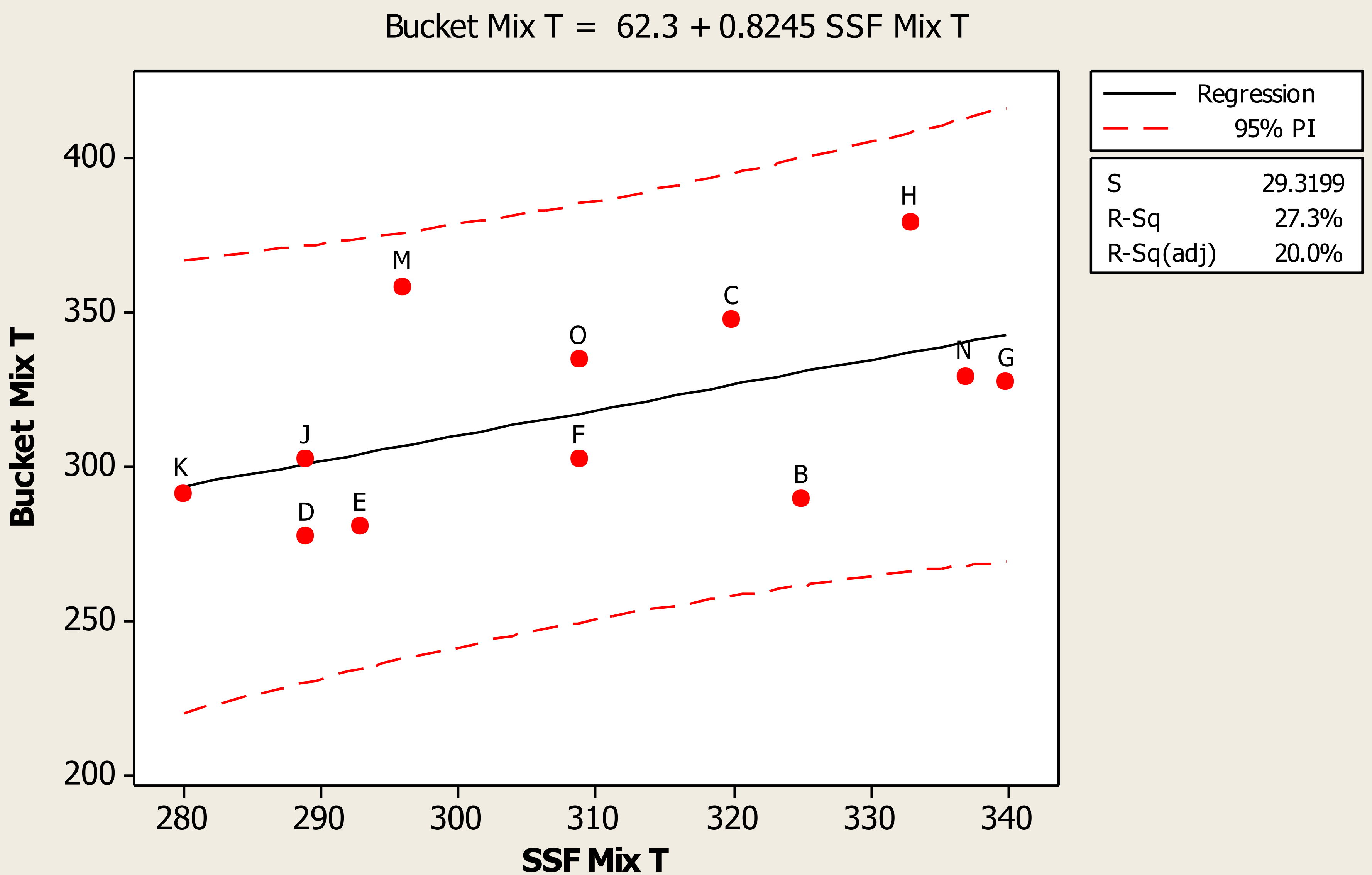
SSF method – Coating w/ Pugmill



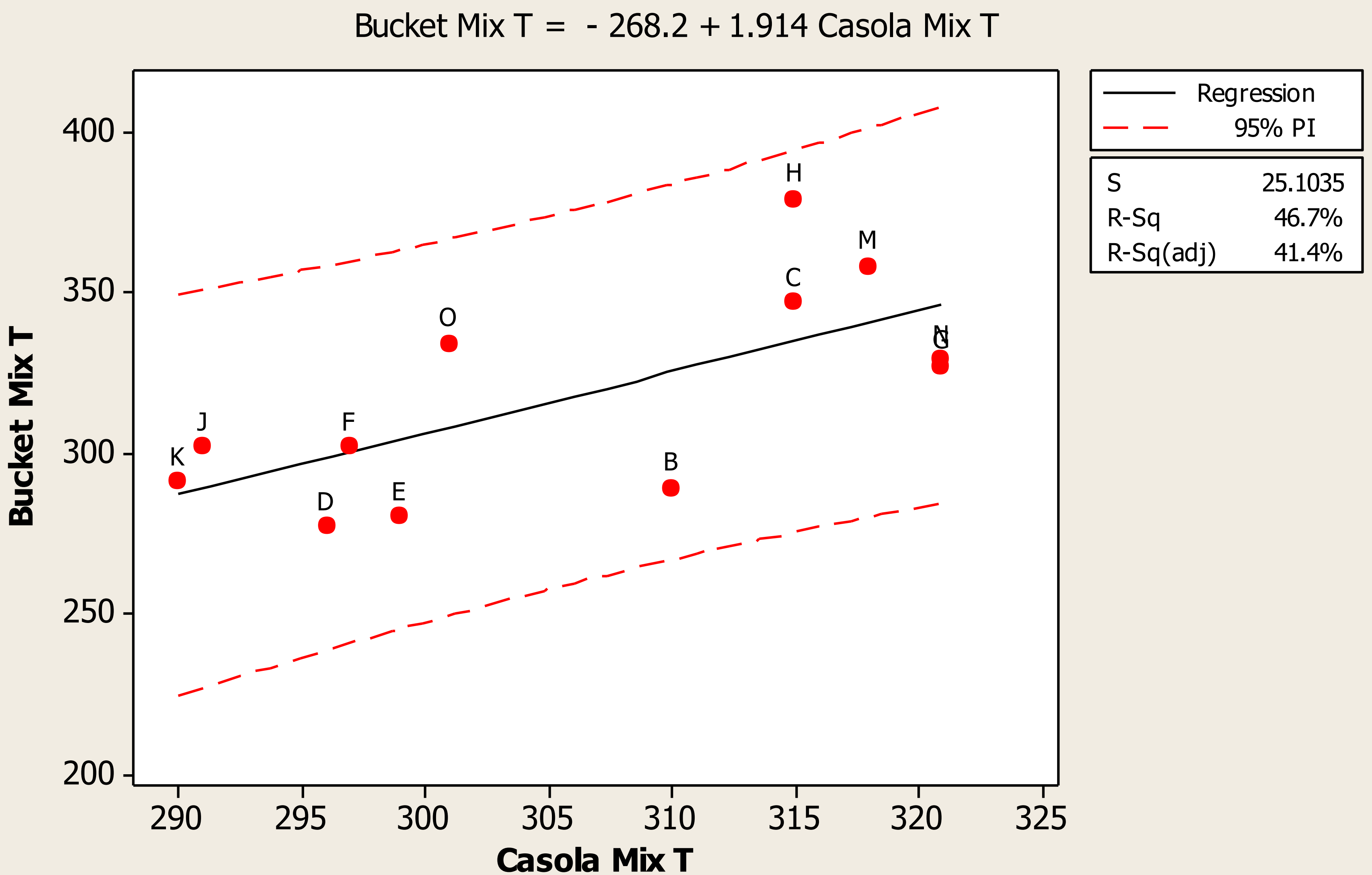
Casola method – Coating w/ Pugmill



SSF method – Coating w/ Bucket Mixer



Casola method – Coating w/ Bucket Mixer



Regressions with Workability Tests

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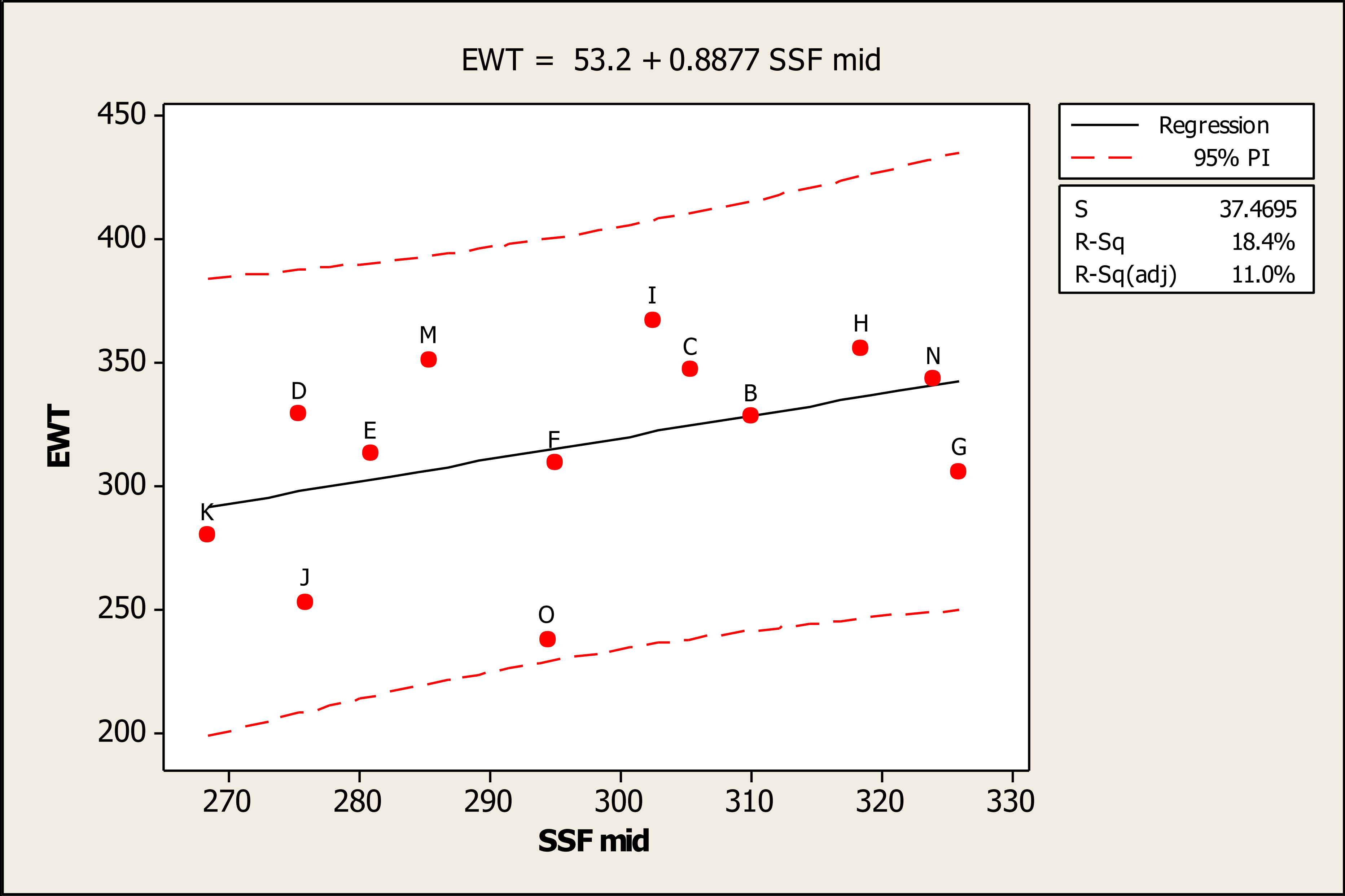
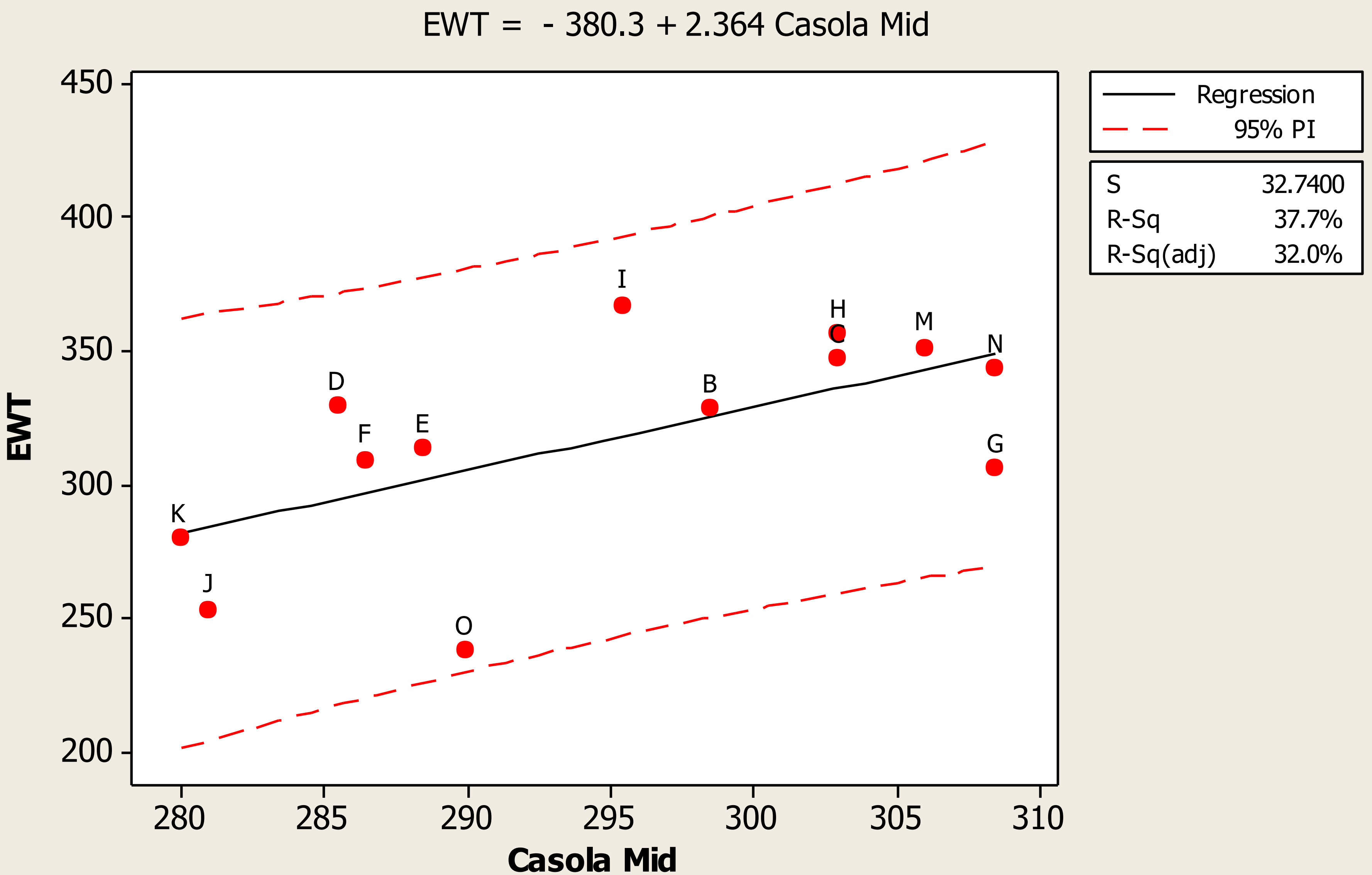
SSF method - Workability

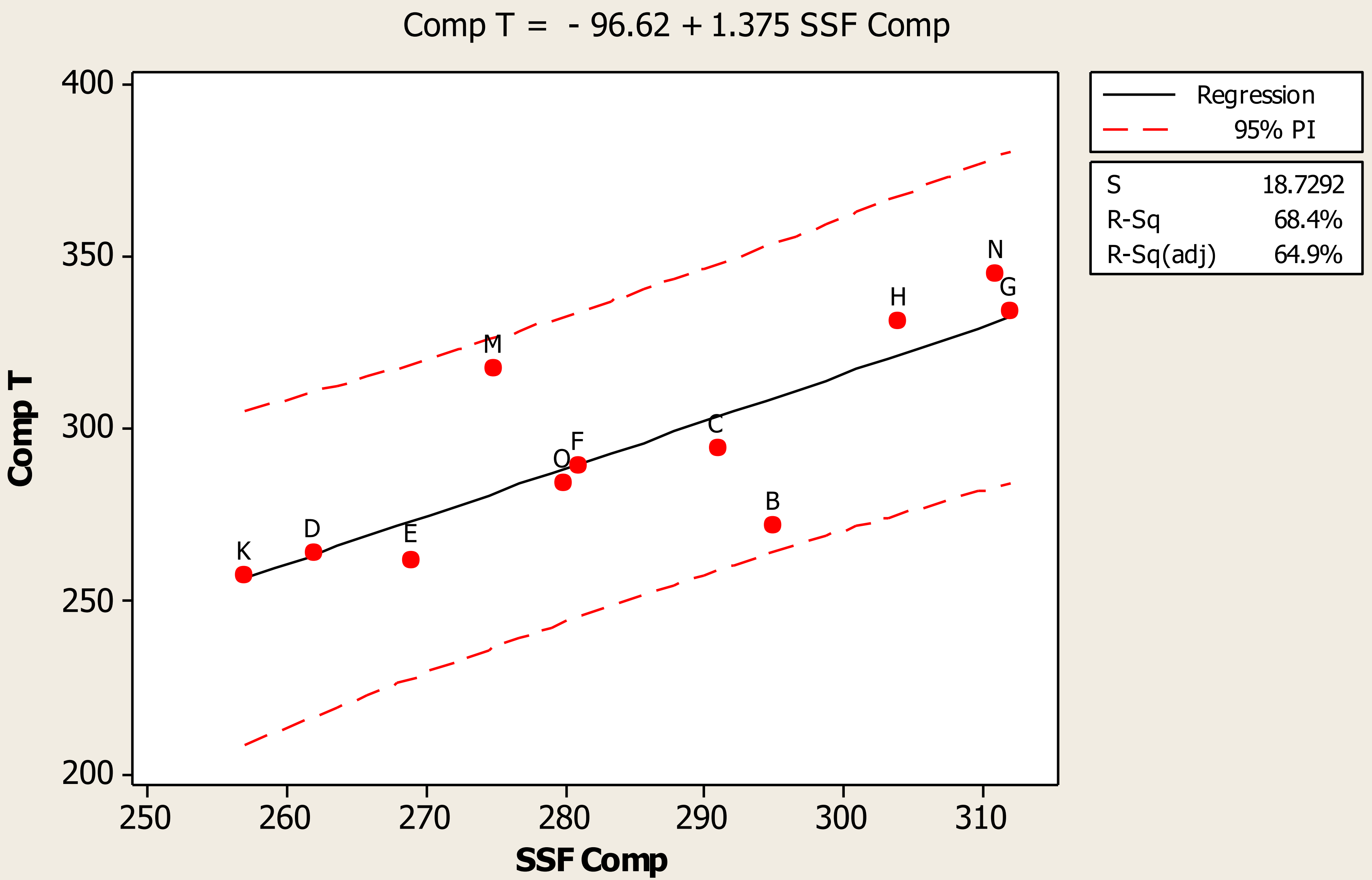


Casola method - Workability

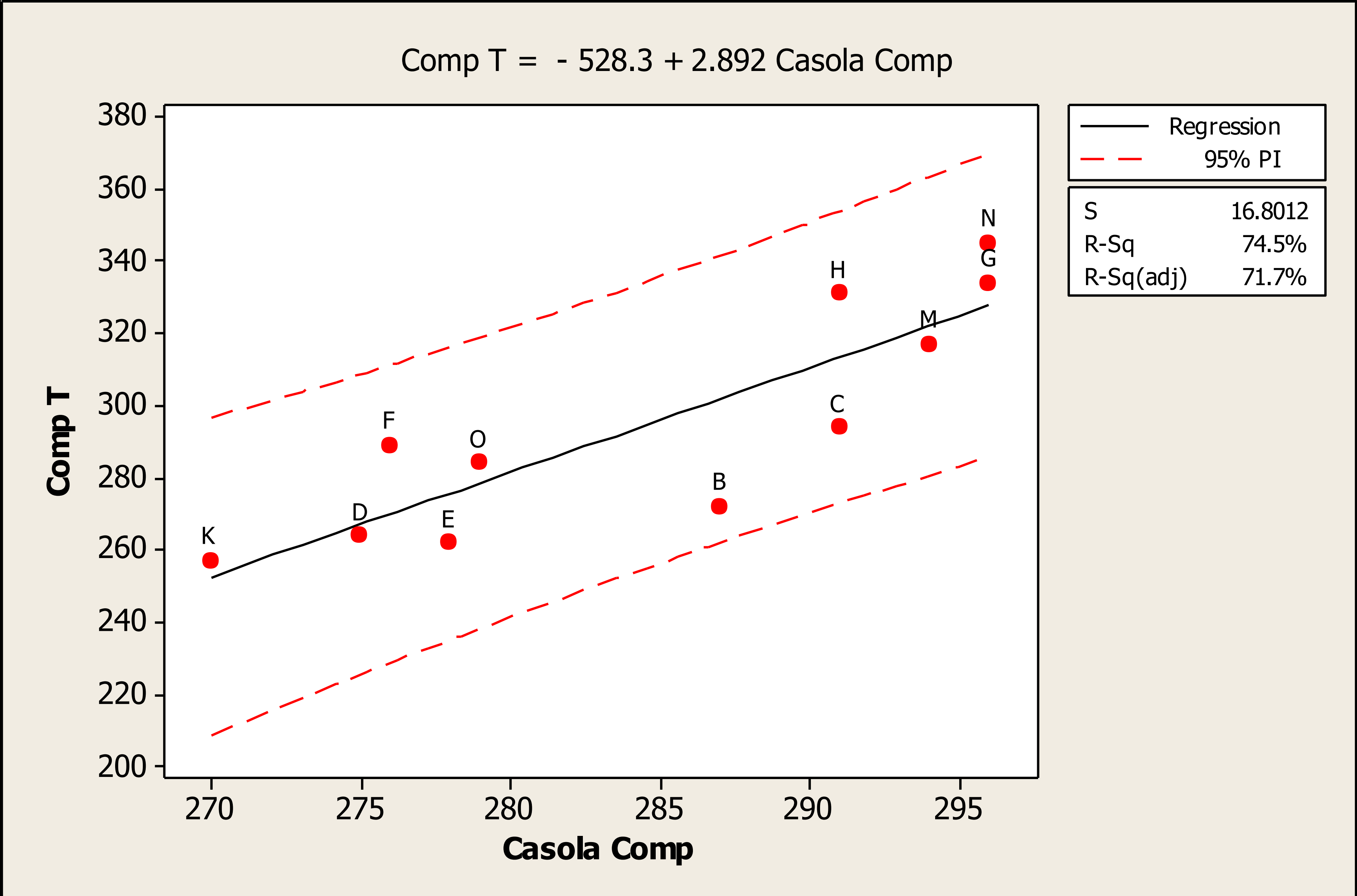


Regressions with Compaction Test Results

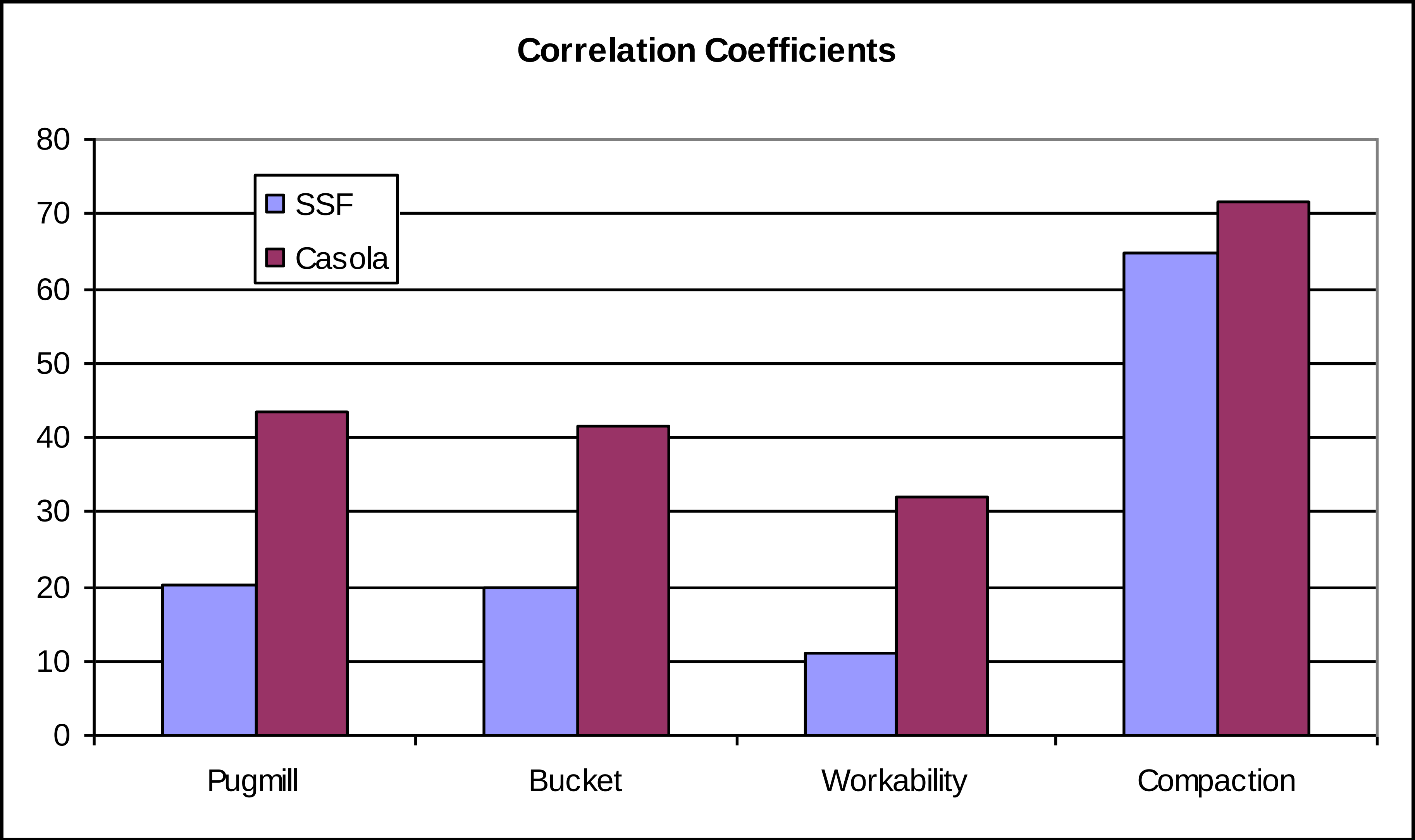
SSF method - Compactability



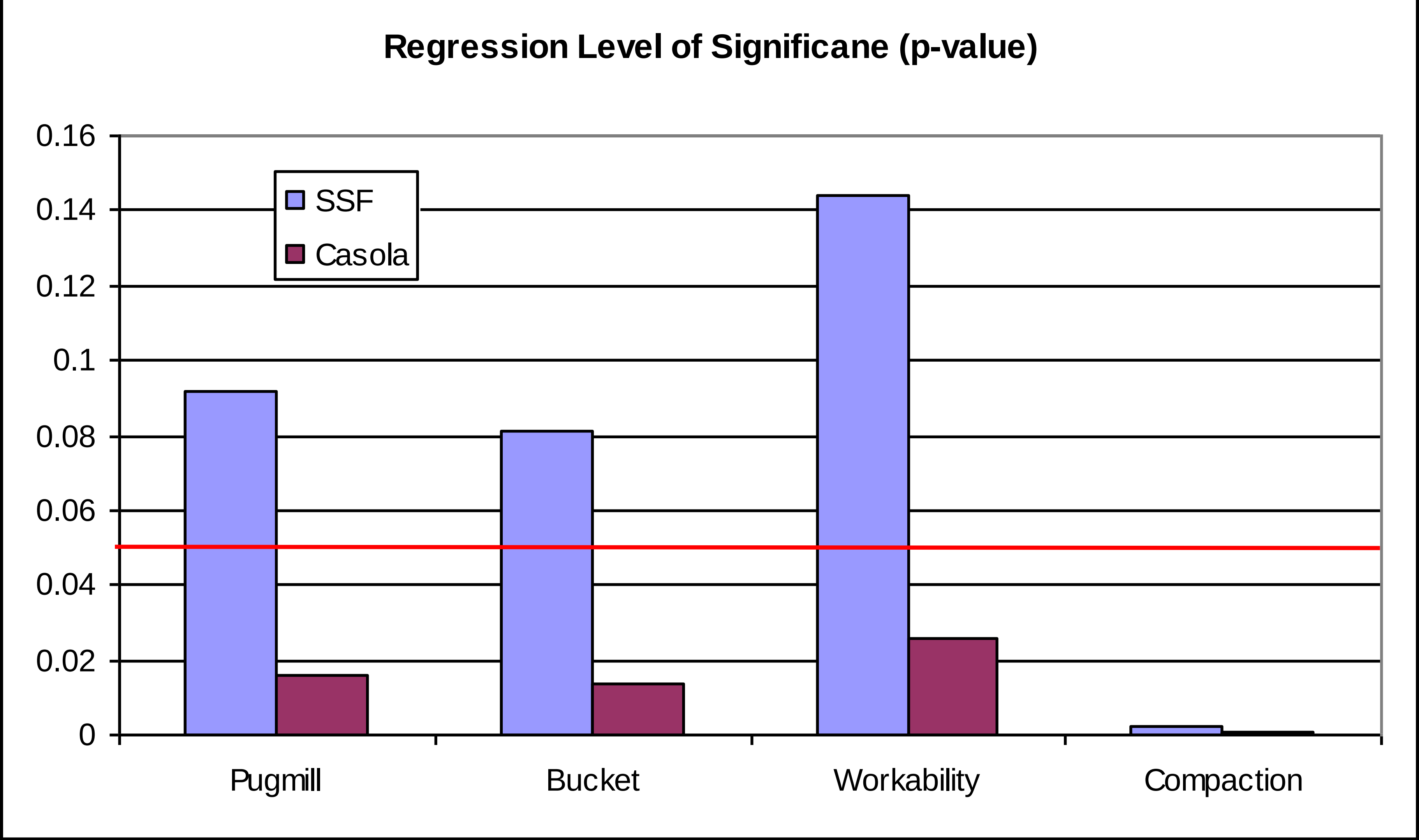
Casola method - Compactability



Statistical Comparison of methods



Statistical Comparison of methods



Selection of Casola Method

- Casola method is simple and uses existing equipment
- It is quick, takes about 40 minutes, hands free operation.
- It provides reasonable temperatures for modified and unmodified binders.
- It provides better correlations to coating, workability, and compactability tests.

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Limitations

The recommended procedure is based only on binder characteristics. Other factors affect coating and compactability include:

- Warm mix additives/processes
- RAP & other recycled materials
- Aggregate & mineral filler characteristics

Smoke & Emissions Potential

- Stroup-Gardiner and Lange
- Oven with Opacity Meter and Internal Balance
- Tests conducted at 130, 150, 170, and 190ºC
- Use to evaluate maximum temperature binder can be used without degrading the binder or causing emission problems.

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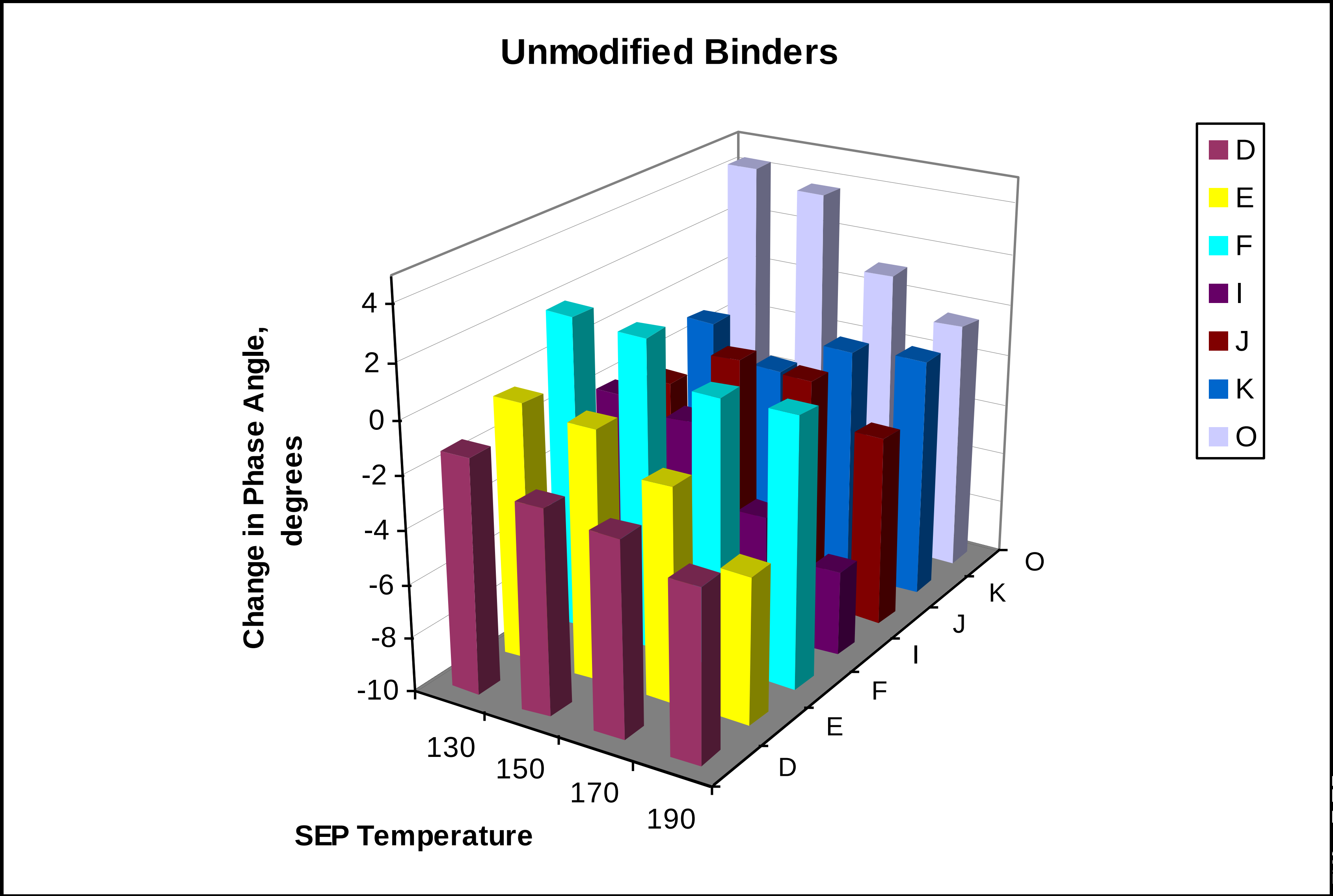
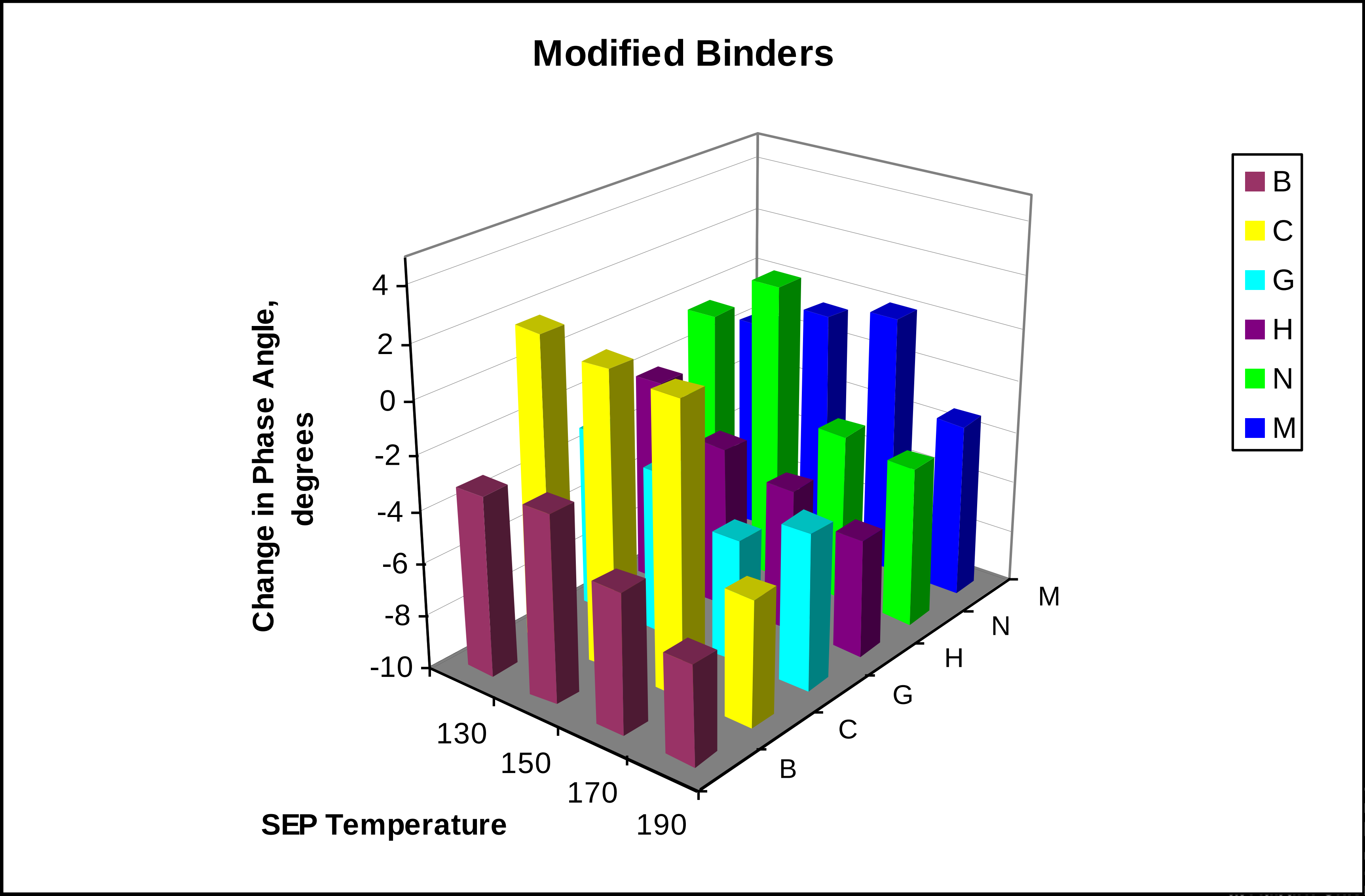
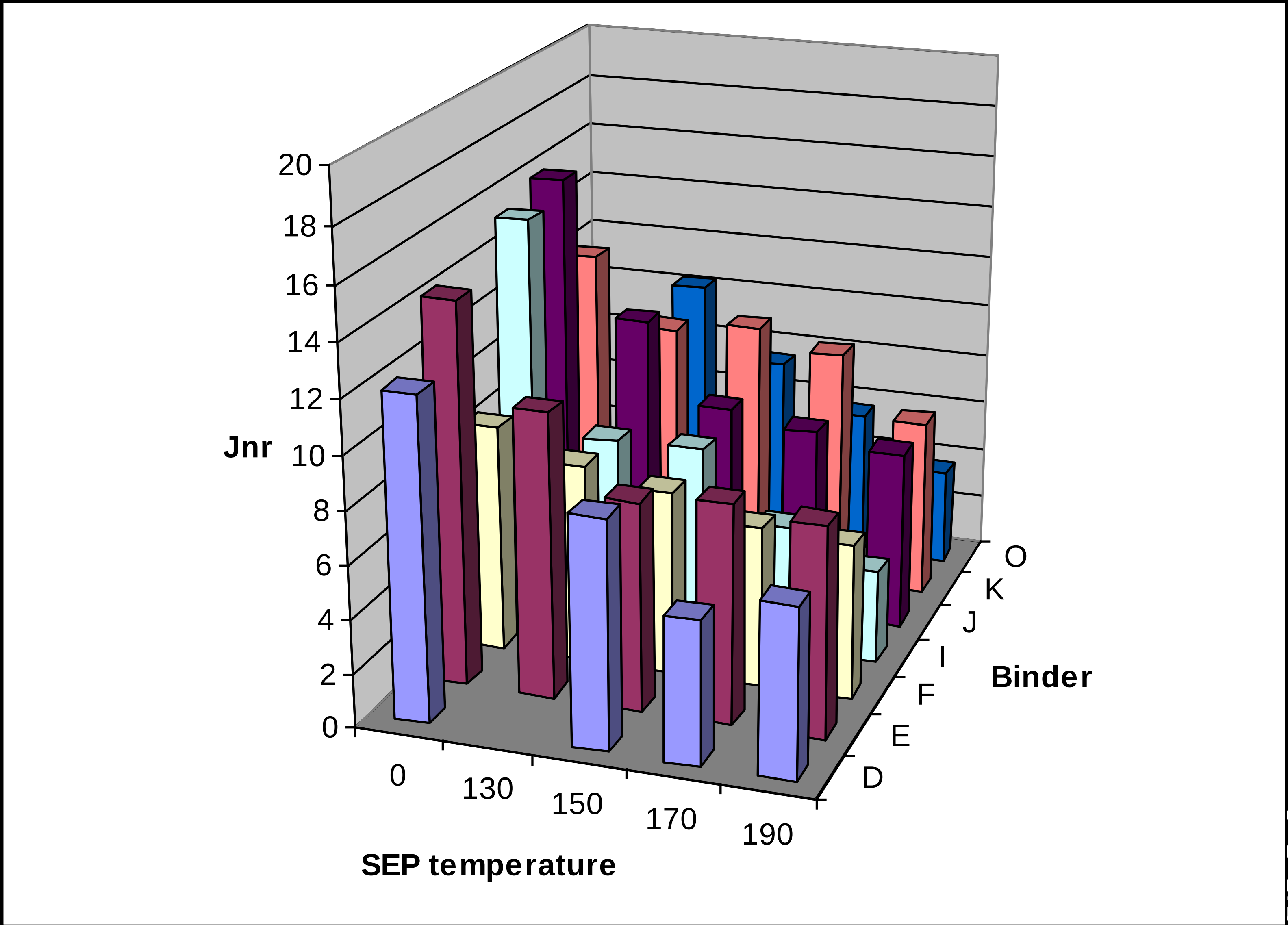
Change in Phase Angle



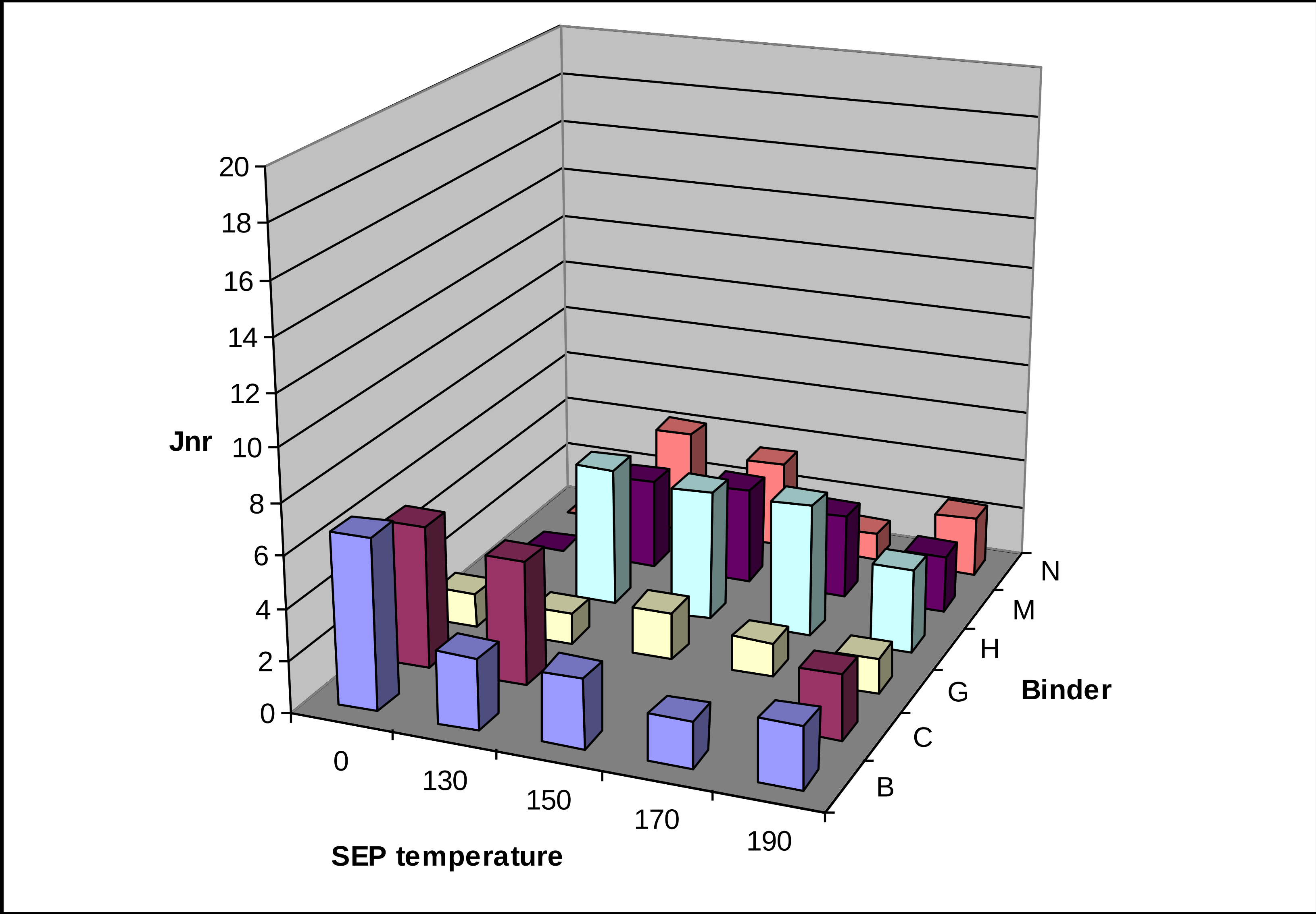
Change in Phase Angle



MSCR Jnr: Unmodified Binders



MSCR Jnr: Modified Binders



Observations on Binder Degradation from SEP test

- Opacity increases with temperature
- Opacity does not appear to be correlated to grade, or modification
- Four binders had mass losses > 1.0% which has been linked to high odor potential
- All binders increased high PG grade one level (e.g. PG 70- to a PG 76)
- Only 1 of 10 binders increased low PG grade level (e.g. -28 to a -22)

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Remaining Work

- Tweak Casola method
- Analysis of validation test results
- Complete IDT mix tests to evaluate degradation
- Write final report

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Thank You!