

Project 0-6607

Search for a Test for Fracture Potential of Asphalt Mixes

OT Sensitivity Evaluation



by

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Austin Riverside Campus, Bldg 118, RTI Conference Room (1st Floor)

November, 2011

Task Update: HMA Mixes

#	Mix Type	Materials	Sample Type	Cracking Resistance (OT Cycles)
1	CAM (Bryan)	6.7% PG 76-22 + Limestone + 1% Lime	Raw materials & plant-mixes	VERY GOOD (>700)
2	Type D (Chico)	5.0% PG 70-22 + Limestone	Raw materials	GOOD (200 to 700)
3	Type D (Atlanta)	5.0 - 6.2% PG 64-22 + Quartzite + 20% RAP	Plant-mix & raw materials	MARGINAL (< 200)
4	Type B (TxDOT)	Limestone	Core	
5	Type C (Laredo)	5.0% PG 64-22 + Crushed Gravel + 1% Lime + 20% RAP	Plant-mix & raw materials	
6	Type D (Childress)	4.9% PG 58-28 + Granite + 1% Lime + 20% RAP	Plant-mix & raw materials	
7	Type C (FW)	4.6% PG 70-22 + Granite + 1% Anti-strip + 15% RAP	Raw materials	
8	Type C (Odessa)	5.8% PG 70-22 + Limestone	Raw materials & plant-mixes	

Task Update: Variability

1) Crack tests – very variable by their nature

	Flexural Beam Fatigue	Flexural Trapezoidal Fatigue	Diametral Fatigue
Stiffness			
Coefficient of Variation (%)	12.3	11.4	19.7
Sample Variance (ln psi)	0.010	0.014	0.015
Cycles to Failure			
Coefficient of Variation (%)	98.7	171.8	65.5
Sample Variance (ln cycles to failure)	0.282	1.696	0.213

SHRP, 1994
(Monismith)

2) For this study; used $COV \leq 30\%$ as reference for acceptable variability

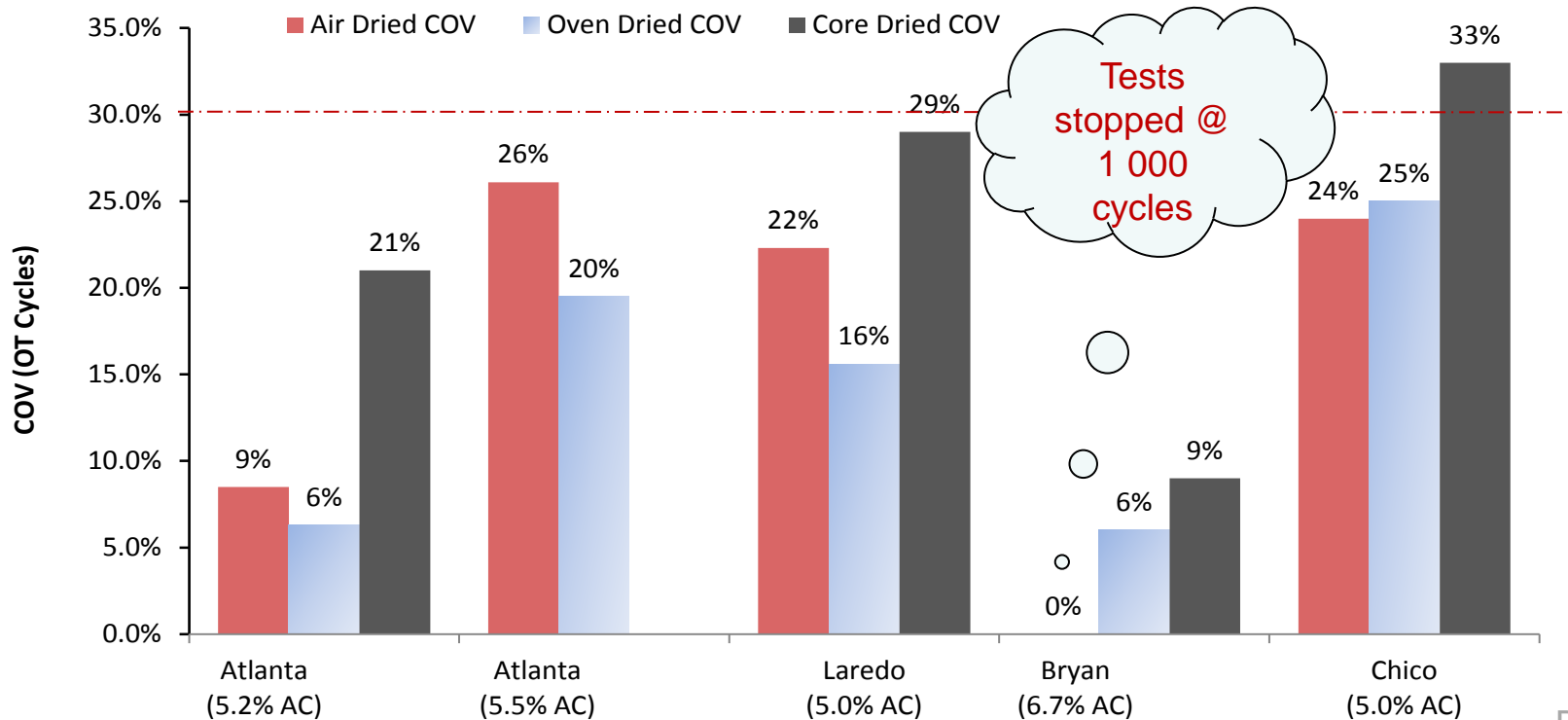
Update: OT Sensitivity Evaluation

#	Factor	Variables	Mixes	Key Finding	Comment
1	Sample replicates	3, 4, & 5	5	Test 5 or 4 specimens & pick best 3	
2	Drying method	Air (room), Oven (104 F), & Core dryer (room)	5	Oven @ 104 °F best followed by Core Dryer	Oven = many samples Core dryer ≤ 10 samples
3	Sample mold size	5" (2), 4.5" (1), 4.5" (2), & 2.5" (1)	3	Use 5" (2) or 2.5" (1)	
4	Sample sitting time	3, 5, 7, 9, 11, 15, & 20 days	3	Test within 5 days of sample molding	Record if tested after 5 days
5	Glue type (3 types evaluated)	(1) Devcon plastic steel putty, (2) Devcon high strength epoxy, & (3) Devcon 2-ton epoxy; all two-part	3	Use Devcon 2-ton 2-part epoxy	
6	Glue quantity (2 ton 2-part epoxy)	14, 16, & 18 grams	3	Use 16±0.5g (16 ml or 2/3)	
7	Plates/sample gap width (teflon/metal strips)	6.25 mm (tape vs. metal bar)	3	New plates are better; easy to align	Challenge is use of metal bar
8	Test loading parameters	0.015 in, 0.02 in & 0.025 in	3	Use 0.025 inch @ 10 sec/cycle	Modifying parameters did not improve repeatability
9	Test temperature differential	73° F, 75° F, 77° F, 79° F, 81° F	3	Use ±2 °F tolerance limit	High variability for > 2 temp differential
10	AV uniformity effect	5%, 6%, 7%, 8%, & 9%	5	7±0.5% gives more consistent results	Use 7±1% for practicality
11	Rest time prior to testing	10 min, 20 min & 30 min	3	Use ≥ 10 min	
12	Sample batching & molding	1 batch 5 or 4 samples vs. 5 batches 5 samples		Individual batching more consistent results	More work & time , i.e., > 2 times

Task 2-2-2: Drying Method.

Air vs. Oven (104 F) vs. Core-drying

- 1) Air = In front of fan @ room temp, min 12 hrs to constant weight
- 2) Oven = @ 104 °F (40 °C), min 12 hrs to constant weight



Air = 92 cycles Oven= 118 cycles Coredry = 91 cycles	Air = 527 cycles Oven= 520cycles Coredry= ??	Air = 25 cycles Oven= 24cycles Coredry= 29 cycles	Air = 1000 cycles Oven= 967 cycles Coredry = 510cycles	Air = 167 cycles Oven= 210 cycles Coredry = 221 cycles
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Best 3 out of 5!



Task 2-2-2: Drying Method..

Analysis & Summary

- Three replicates
- Oven more consistent results with low variability followed by Core Dryer
- Recommendation → Use Oven drying
- Challenge is consistently keeping a 104 °F oven when OT sample drying is needed!!
- Therefore, consider Core Dryer, particularly if less than 10 samples

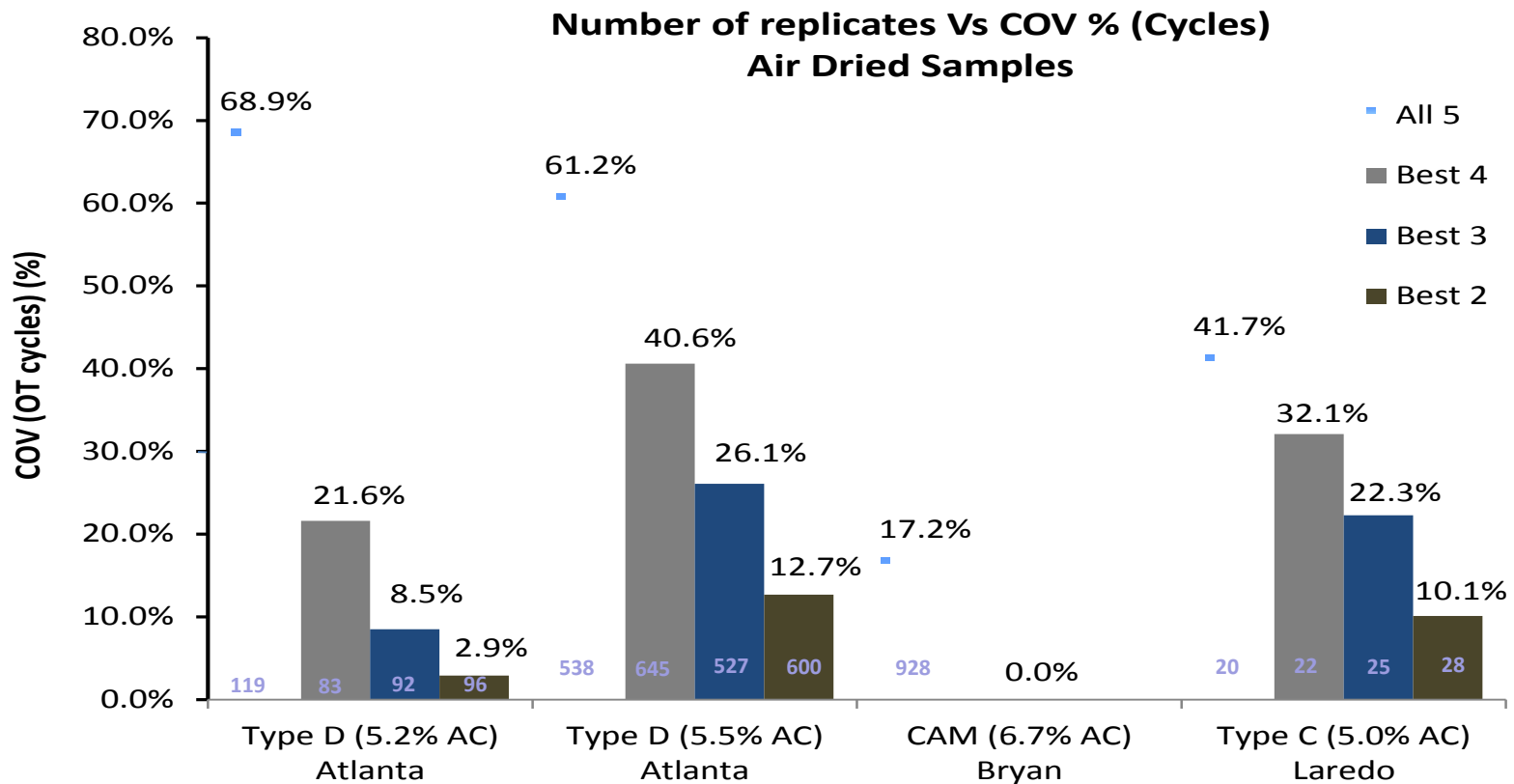


Tex-248-F Item 5.2.3

- Consider revising from:
 - “Dry the trimmed specimen at a maximum temperature of $60 \pm 3^{\circ}\text{C}$ ($140 \pm 5^{\circ}\text{F}$) to constant weight. Maximum drying time should be 24 hours. Discard all samples that are in the oven more than 24 hours.”
- To:
 - “Dry the trimmed specimen at a maximum temperature of $40 \pm 3^{\circ}\text{C}$ ($104 \pm 5^{\circ}\text{F}$) to constant weight. Oven temperature should be kept constant throughout the sample drying process. Minimum drying time should be 12 hrs and should not exceed 24 hrs. Discard all samples that are in the oven more than 24 hrs.”

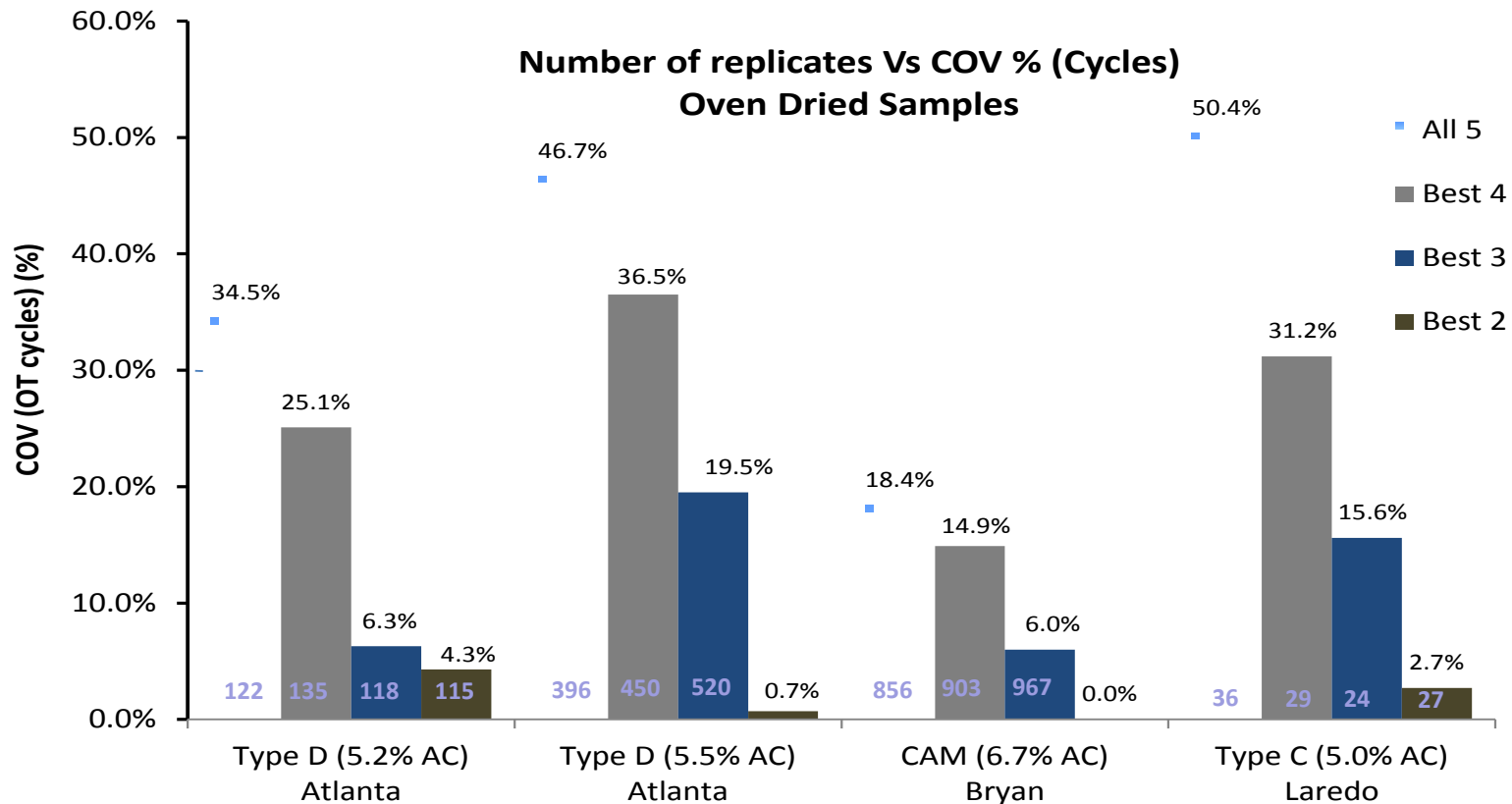
Task 2-2-6: Replicate Specimens.

Air drying - In front of fan @ room temp, min 12 hrs to constant weight
 Tested 5 replicates for each mix.



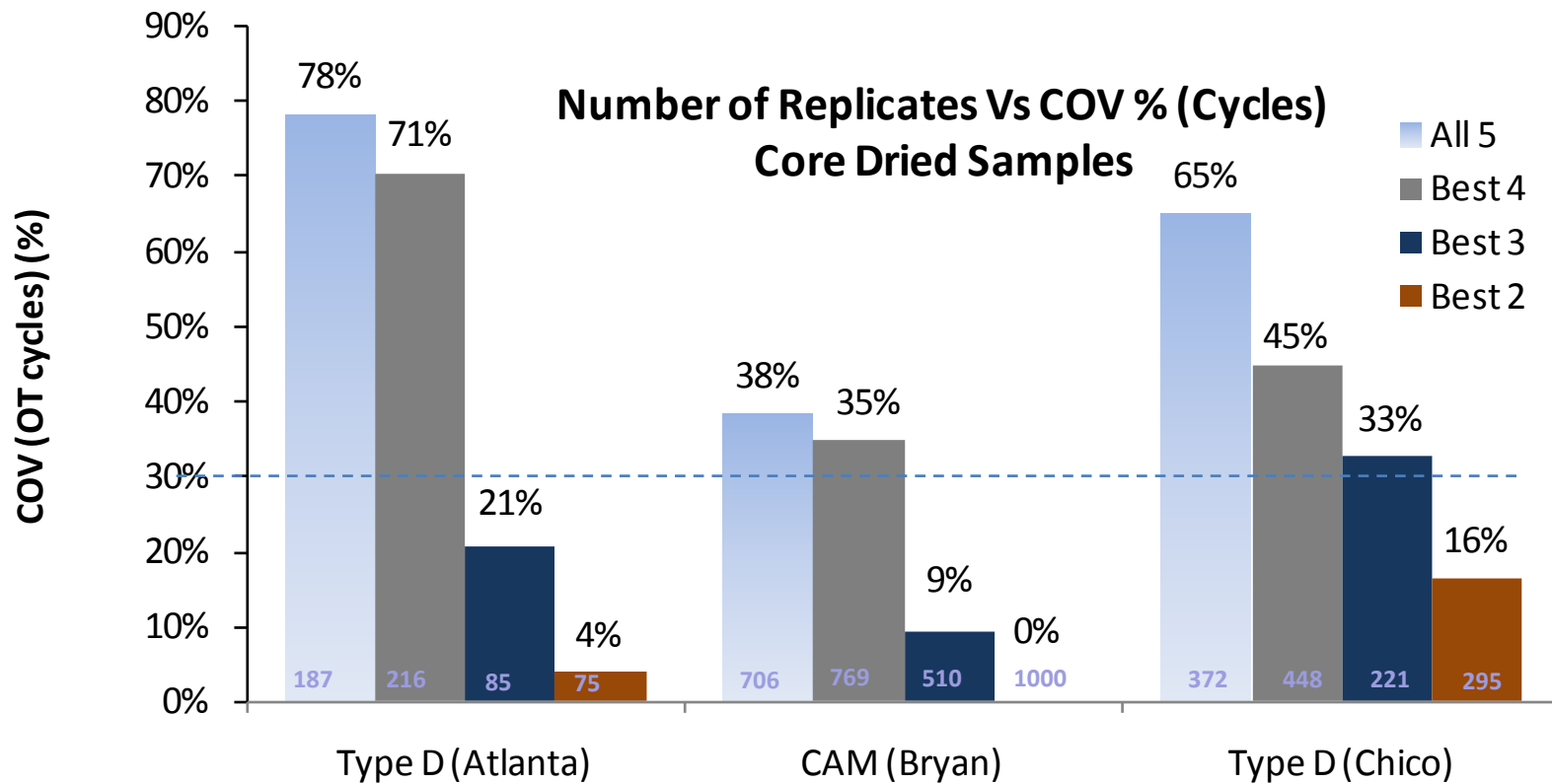
Task 2-2-6: Replicate Specimens..

Oven drying - @ 104 °F (40 °C), min 12 hrs to constant weight
 Tested 5 replicates for each mix.



Task 2-2-6: Replicate Specimens..

Core drying: vacuum/sucking process, ≤ 30 min per sample



Replicate Specimens...

Analysis & Summary

- Best 3 or 2 gives lowest variability without significantly affecting average OT cycles
- Two → not good statistical representation
- Proposal → test 5 or 4 replicates & pick best 3 based on lowest COV; use Macro; Fishers
- Sample size - mold 5" tall & cut 2 OT specimens or mold 2.5" & cut 1 OT specimen – OK as long as AV is uniform – see next slides!!
- **4.5" tall & cut 1 – too wasteful & didn't improve repeatability**

Tex-248-F Item 5.1.1

- **Consider revising to read as:**
 “Use ~~three~~ **five or four** cylindrically molded specimens according to Section 4.”





Tex-248-F Item 6.2

- **Consider adding Item 6.2 as follows:**
 “For the final analysis and reporting, pick the results of the best 3 replicates out of 5 or 4 based on the lowest COV (can use Macro if needed) and report the following additional data:
 - The average peak load
 - The average OT cycles
 - The Stdev and COV”

Task 2-2-10: Sample Mold Size

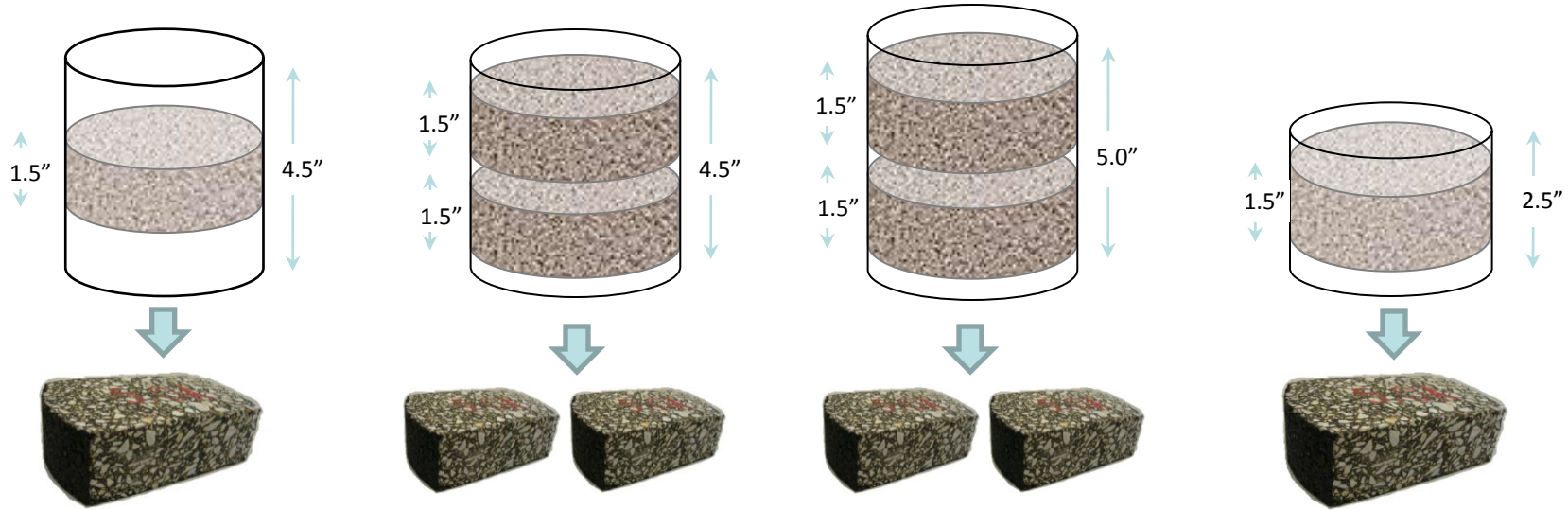
Shifted from 2.5" to 4.5" to help address variability issues:

- Cutting 1 from 4.5" has NOT helped address variability
- But instead just increased work load & material wastage

Mold sample size configuration @ average 7% AV	4.5"	4.5	5.0	2.5
				
Molded Sample Volume (in. ³)	118	118	132	66
OT Specimen Volume (in. ³)	25	50	50	25
Material Wastage in volume	80%	57%	60%	60%
Material Wastage in Weight	79%	56%	63%	59%

Hence, the need to revisit this aspect so as to optimize material & work load!!

Task 2-2-10: Sample Mold Size



Atlanta Type D (US 59S)
 PG 64-22 + Quartzite +
 20% RAP

Plant-mix – Best 3 of 5 replicates

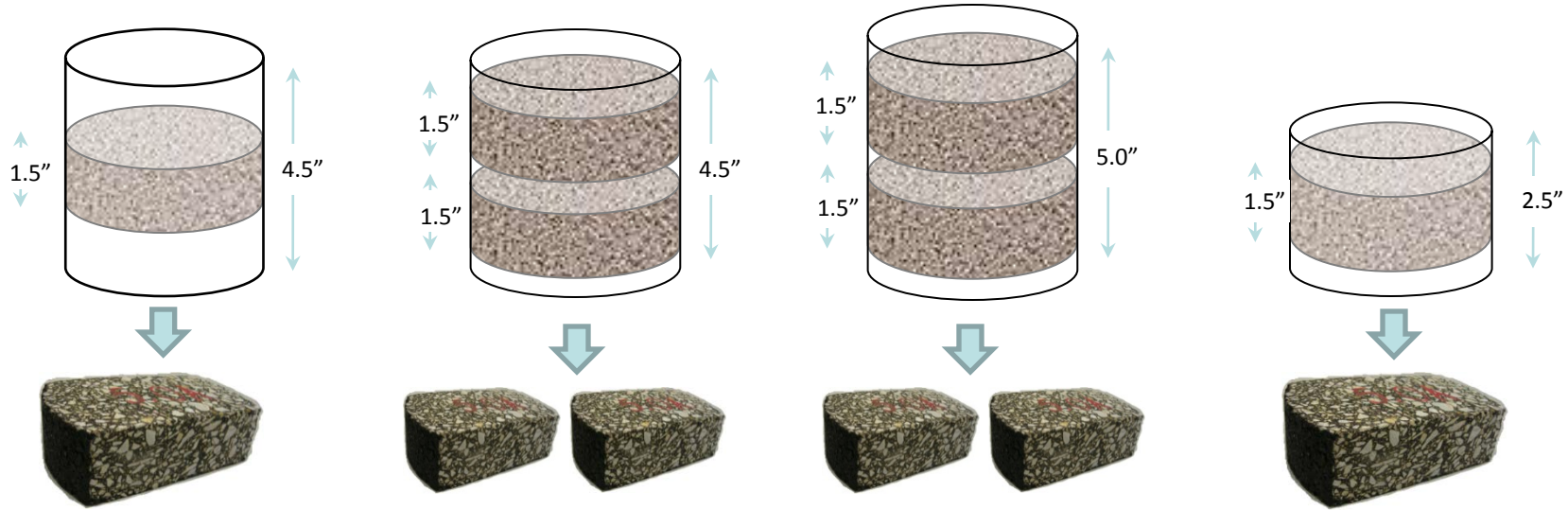
**Molded Sample
 Height 4.5”
 (1 OT Specimen)**

**Molded Sample
 Height 4.5”
 (2 OT Specimen)**

**Molded Sample
 Height 5.0”
 (2 OT Specimen)**

**Molded Sample
 Height 2.5”
 (1 OT Specimen)**

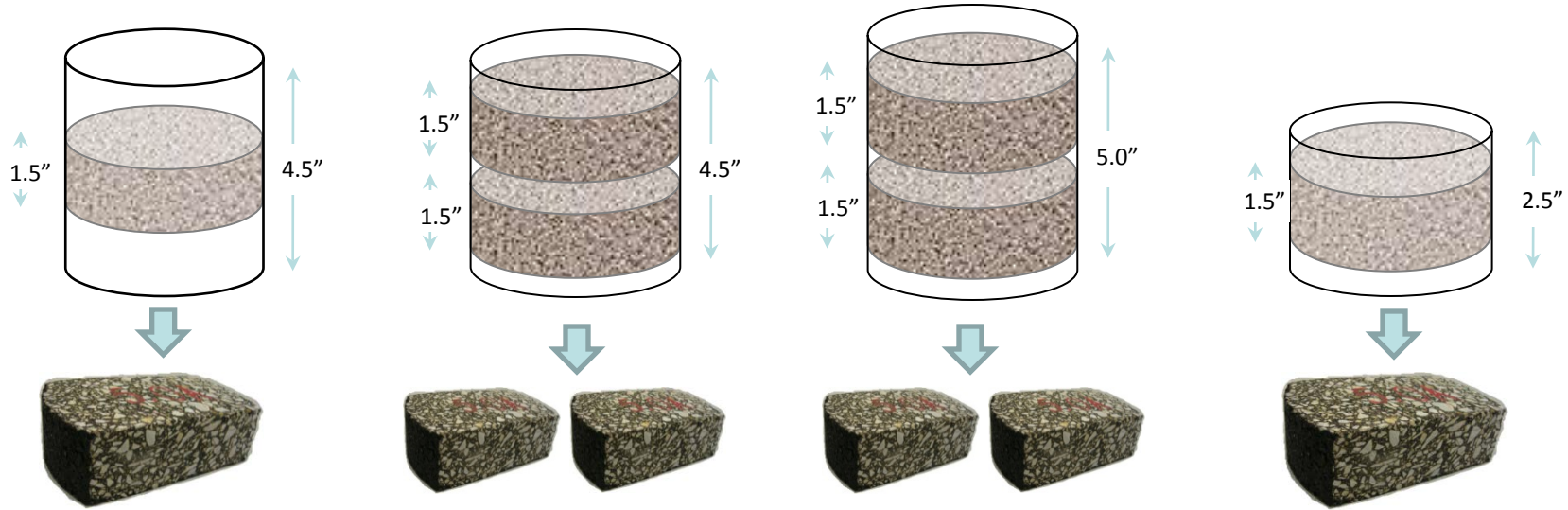
Peak Load (lb)	Average	706	676	581	890
	COV (%)	2%	2%	22%	3%
OT Cycles	Average	180	176	150	170
	COV (%)	26%	24%	13%	27%
Air Void (%)	Average	6.4	7.4	7.5	6.5
	COV (%)	6%	3%	2%	7%



Laredo Raw Materials Type C		4.5" Sample (1 Specimen)	4.5" Sample (2 Specimen)	5.0" Sample (2 Specimen)	2.5" Sample (1 Specimen)
Peak Load (lb)	Average	618	542	578	687
	COV (%)	2%	6%	3%	1%
OT Cycles	Average	92	61	83	54 ???
	COV ($\leq 30\%$)	8%	11%	7%	20%
Air Void (%)	Average	6.8%	6.5%	8.5%	6.0%
	COV (%)	3%	9%	10%	7%



*Shifting from 2.5" to 4.5" has NOT addressed the variability issue; hence, the need to revisit this aspect so as to optimize both material & work!!



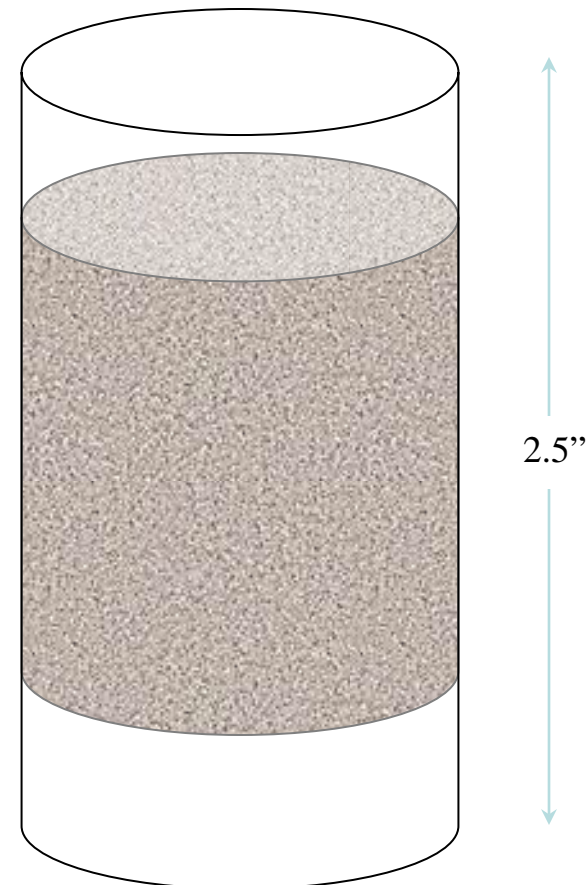
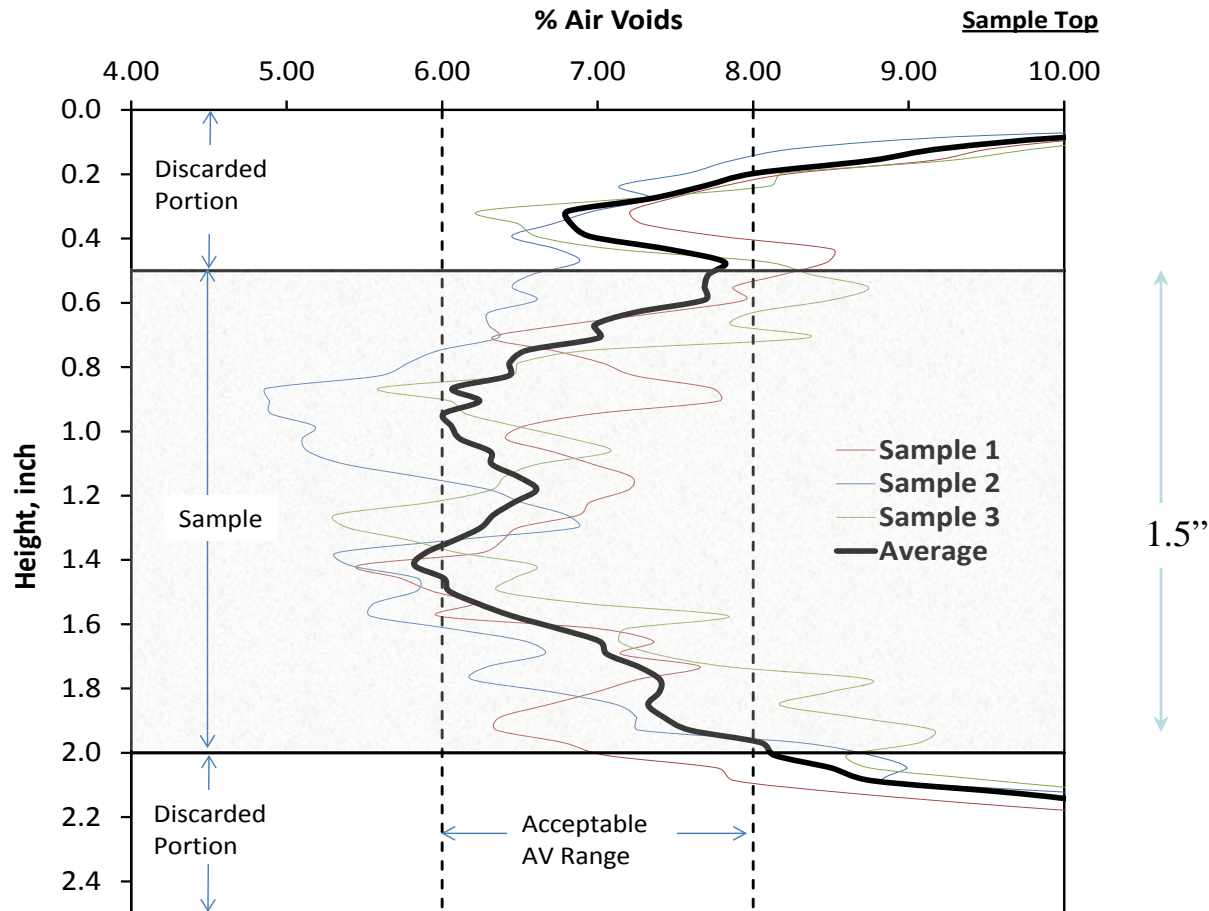
Chico Type D		4.5" Sample (1 Specimen)	4.5" Sample (2 Specimens)	5.0" Sample (2 Specimens)	2.5" Sample (1 Specimen)
Peak Load (lb)	Average	516	388	609	632
	COV (%)	1%	1%	4%	4%
OT Cycles	Average	210	230	203	89 ???
	COV (%)	25%	27%	28%	11%
Air Void (%)	Average	7.3%	7.7%	7.8	6.4%
	COV (%)	2%	11%	3%	1%

*Shifting from 2.5" to 4.5" has NOT addressed the variability issue; hence, the need to revisit this aspect so as to optimize both material & work!!

Task 2-2-3: AV & X-Ray CT.

Air Void Distribution for a Molded sample of 2.5" height
1 OT Specimen Cut from Each Sample

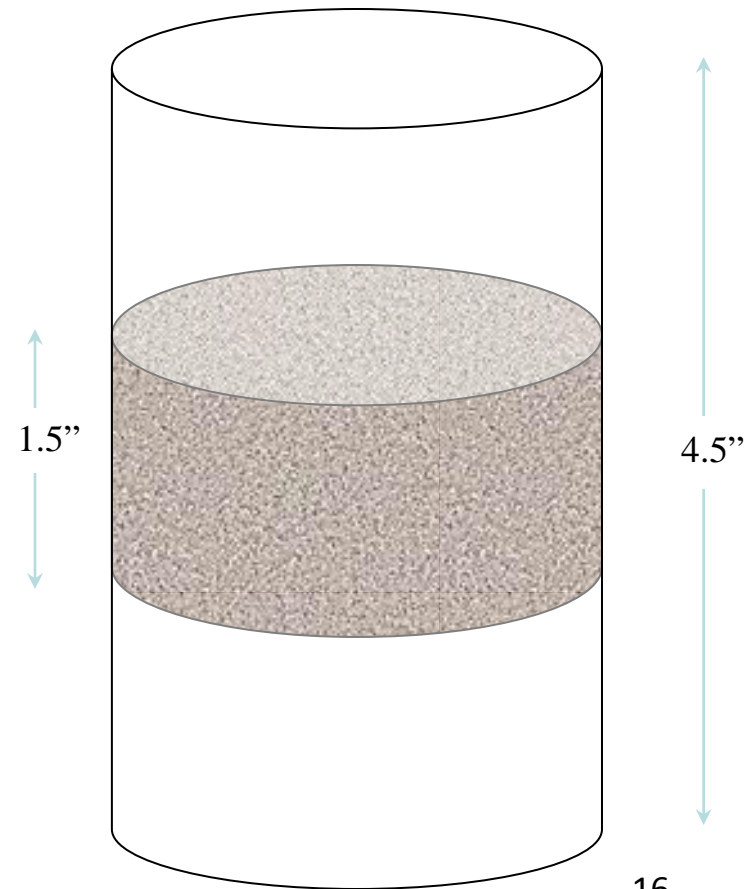
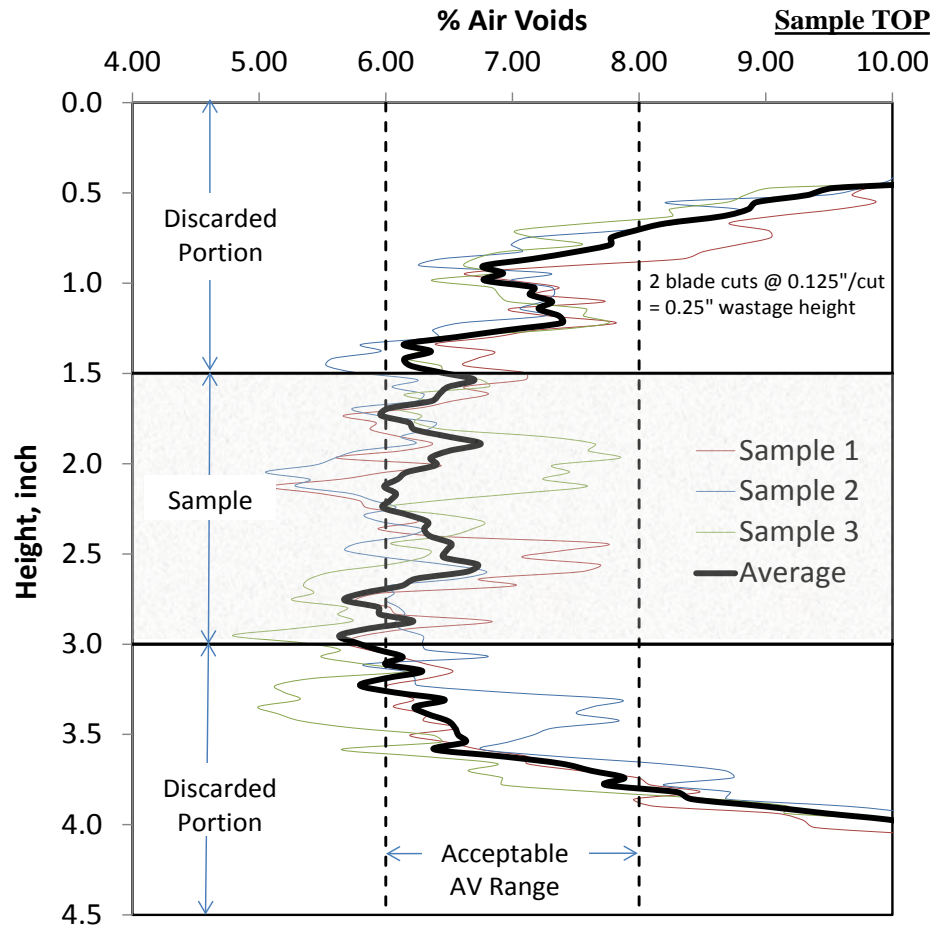
Atlanta Type D (US 59S)
5.1% PG 64-22 + Quartzite +
20% RAP



Task 2-2-3: AV & X-Ray CT..

Air Void Distribution for a Molded sample of 4.5" height
1 OT Specimen Cut from Each Sample

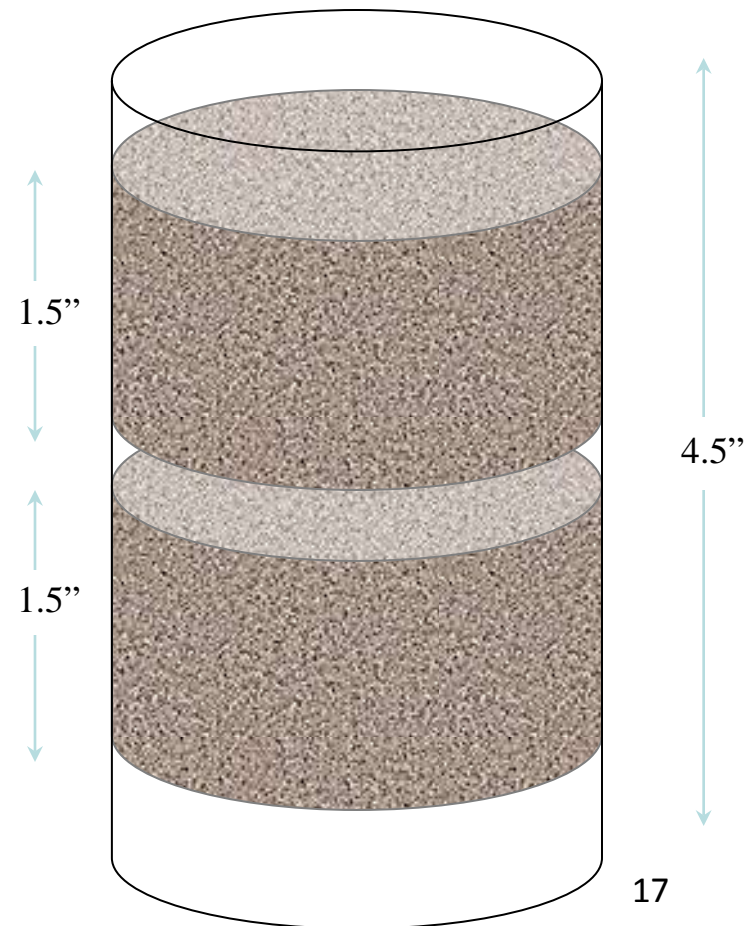
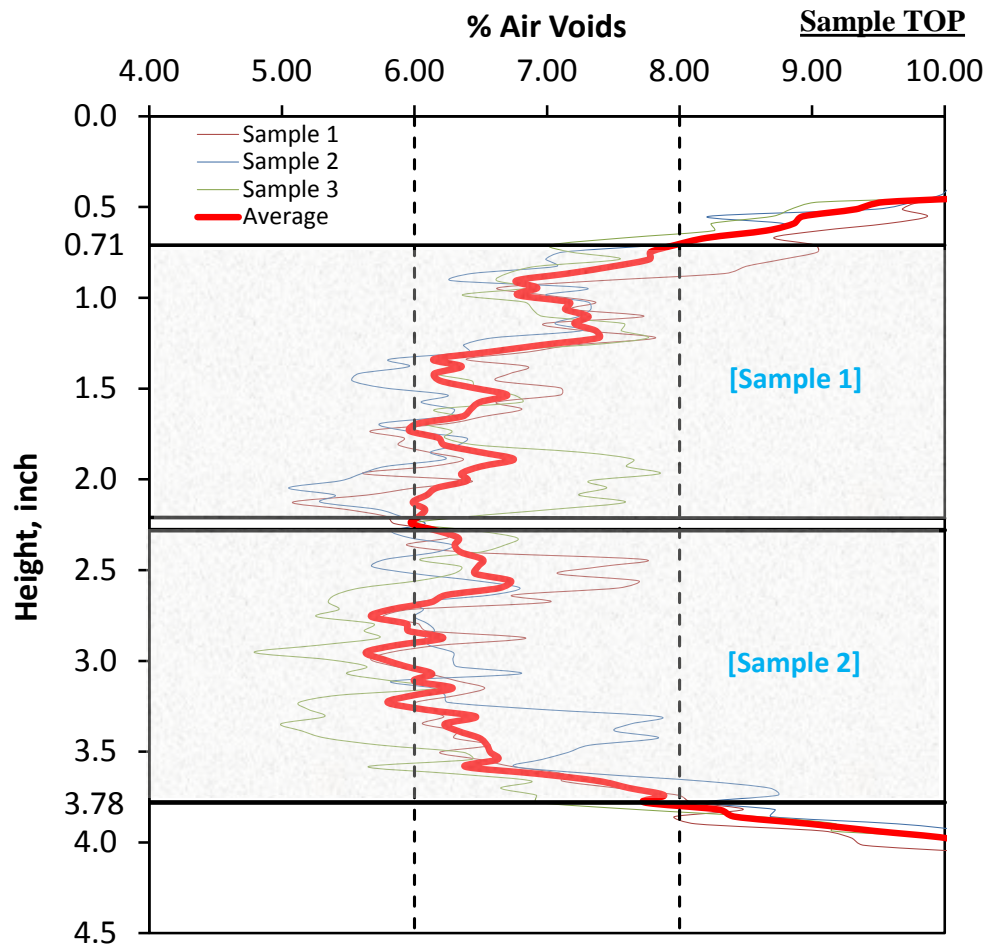
Atlanta Type D (US 59S)
5.1% PG 64-22 + Quartzite +
20% RAP



Task 2-2-3: AV & X-Ray CT..

Air Void Distribution for a Molded sample of 4.5" height
2 OT Specimen Cut from Each Sample

Atlanta Type D (US 59S)
5.1% PG 64-22 + Quartzite +
20% RAP



Task 2-2-3/10: Sample Mold Size...

Analysis & Summary

To optimize material & work load, considering 5 or 4 test specimens will be required:

- Mold three or two 5" high (6"φ) samples & then, cut 2 OT specimens from each,

or

- Mold five or four 2.5" high (6"φ) samples & then, cut 1 OT specimens from each

Tex-248-F Item 4.1

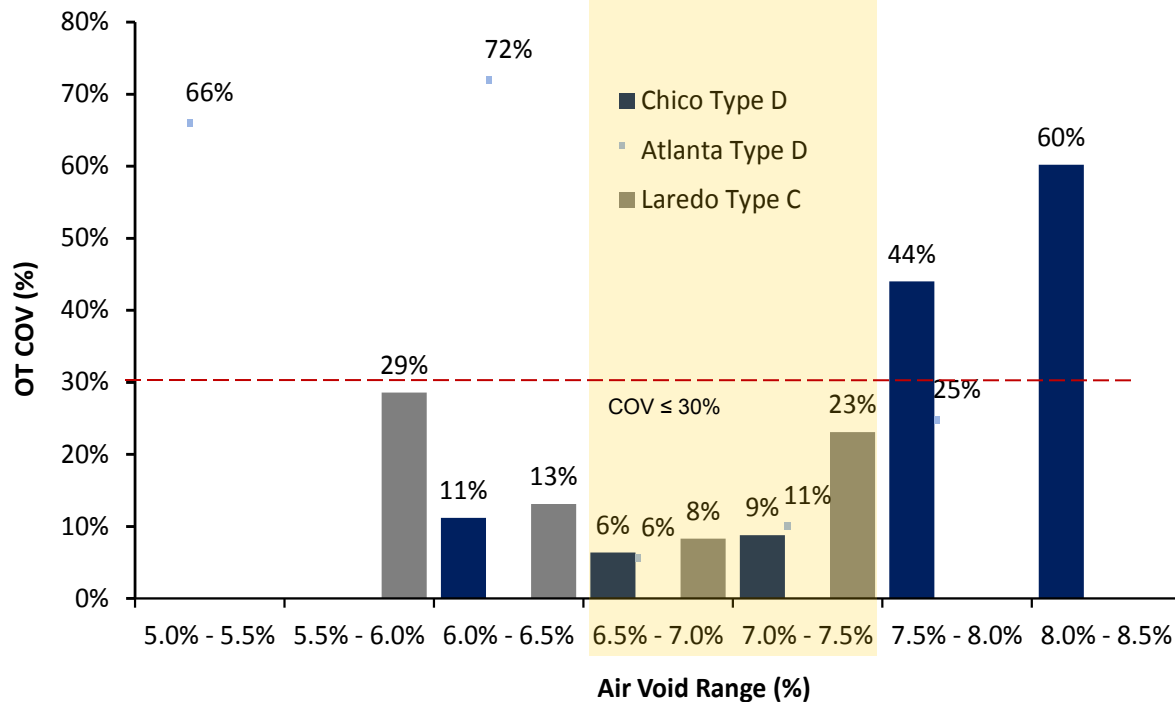
- Consider revising to read as:
 "and specimen height must be 127 ± 5 mm (5.0 ± 0.2 in.) or 63.5 ± 5 mm (2.5 ± 0.2 in)"

Tex-248-F Item 5.1.1

- Consider revising as follows:
 "Use cylindrically molded specimens according to Section 4: a) for the 5 in. mold height, trim 2 OT samples from each, and b) for the 2.5 in. mold height, trim 1 OT sample from each."

Task 2-2-3: AV & X-Ray CT..

OT COV at Different Specimen Air Void Range



AV range	Average OT Cycles		
	Chico	Atlanta	Laredo
5.0% - 5.5%	-	83	-
5.5% - 6.0%	-	176	55
6.0% - 6.5%	89	187	49
6.5% - 7.0%	254	116	92
7.0% - 7.5%	80	144	53
7.5% - 8.0%	162	188	-
8.0% - 8.5%	165	-	-

Task 2-2-3: AV Tolerance &

Analysis & Summary

- $\pm 0.5\%$ AV tolerance gives more consistent results
- Proposal: Target $7 \pm 0.5\%$ AV
- Recommendation: However, $7 \pm 0.5\%$ AV maybe impractical to achieve; therefore stay @ $7 \pm 1\%$

Tex-248-F Item 4.1.1

- Consider adding the following sentence:

“If practically possible however, the $93 \pm 0.5\%$ target density is preferred for better consistency in the OT results.”

Task 2-2-8: Glue Types

[1] Devcon Plastic Steel 5 Minute Epoxy Putty



[2] Devcon High Strength Epoxy



[3] Devcon 2 ton Epoxy S-31

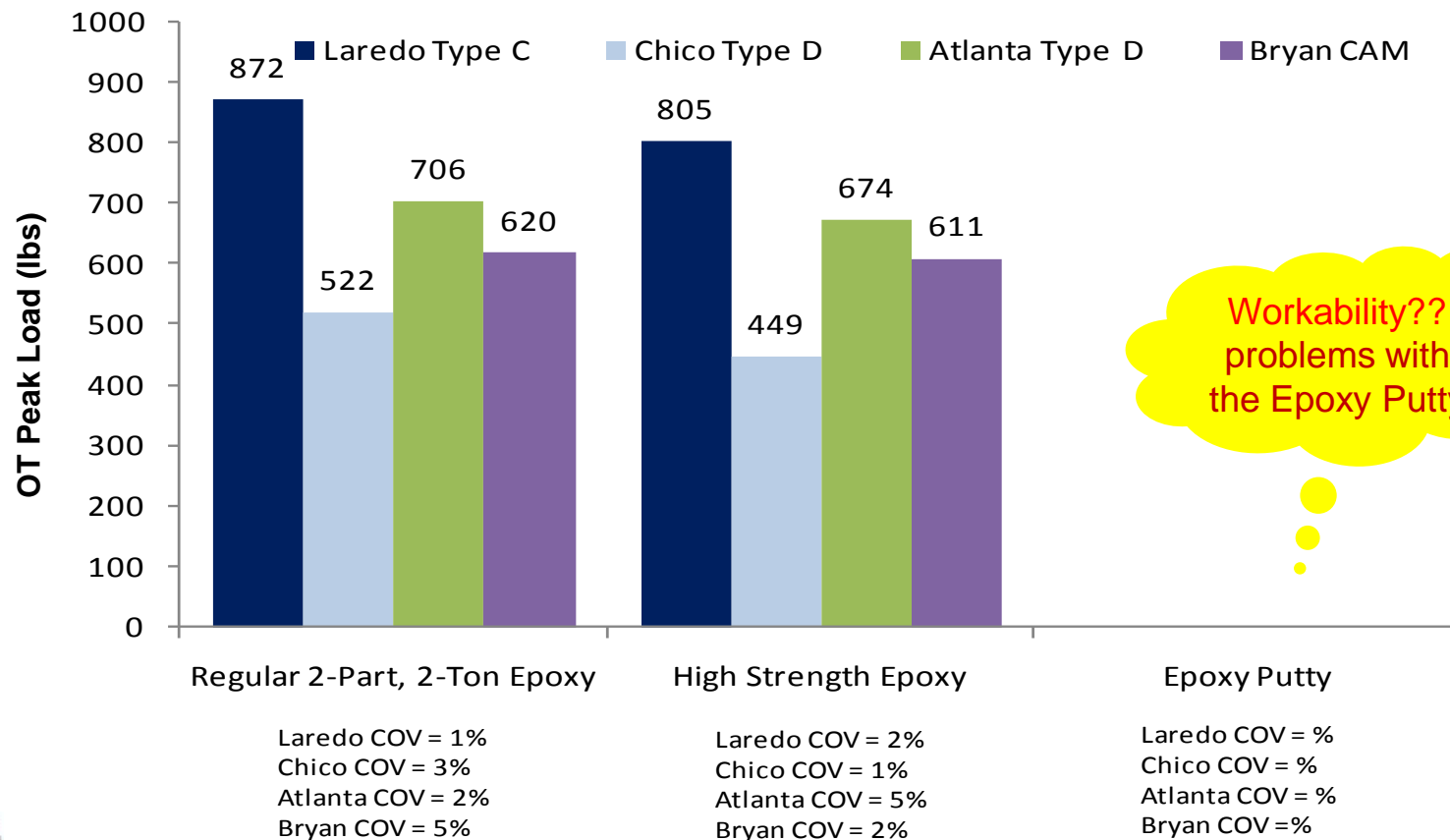


Item	[1]	[2]	[3]
Strength	No strength listed	1500 psi	2500 psi
Curing time (full strength)	16 hrs (overnight)	1 hr (overnight)	8 hrs (overnight)
Price1	\$43.00/1 lb container	\$6.25/tube (2 sets)	\$3.50/tube (2 sets)
Price2	\$5.37/sample	\$4.68/sample	\$2.62/sample
Qty per sample	64±0.5 grams	16±0.5 grams (16±0.5 mls)	16±0.5 grams (16±0.5 mls) [or 2/3 tube]
Comment	Workability issues, weigh separately, can't spread easily, time-consuming, difficulty to clean, costly	OK, but relatively costly	OK (TTI uses this one)

1 g/mls

Task 2-2-8: Glue Type

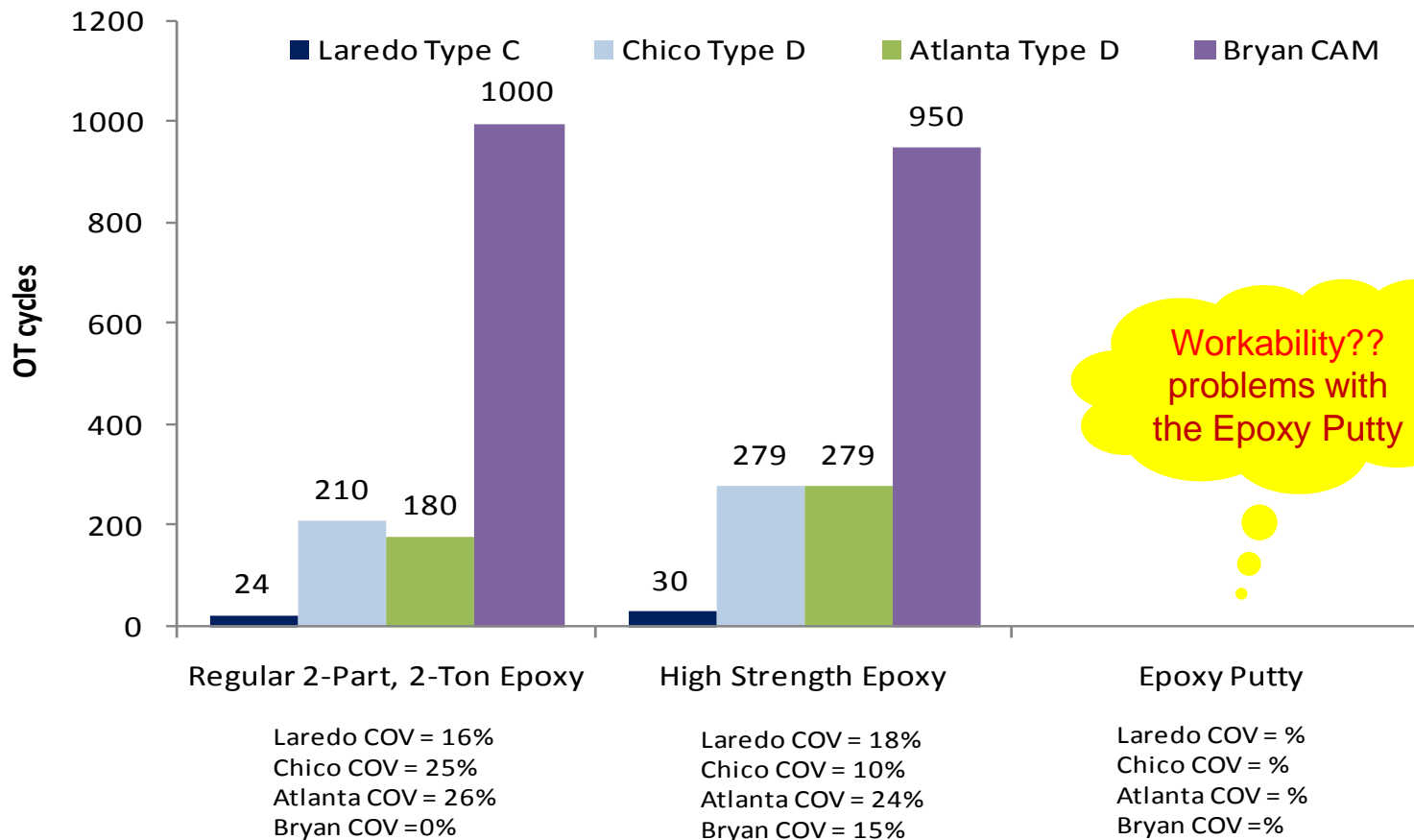
Comparison of OT Peak Loads & COV



Workability??
problems with
the Epoxy Putty

Task 2-2-8: Glue Type

Comparison of Number of OT Cycles & COV

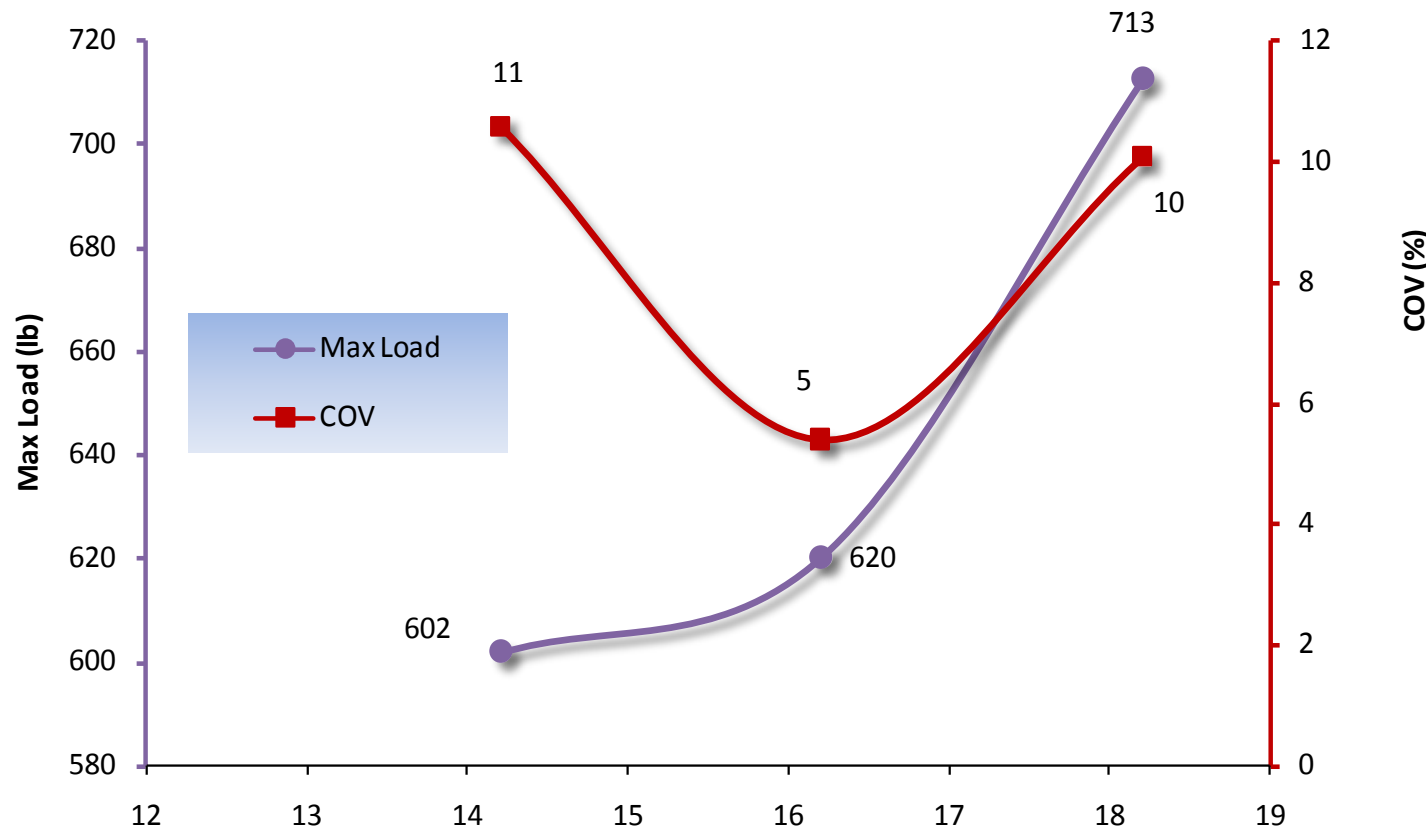


Task 2-2-8: Glue Quantity.

Two-Part 2 Ton
Epoxy Resin



Task 2-2-8: Glue Quantity..



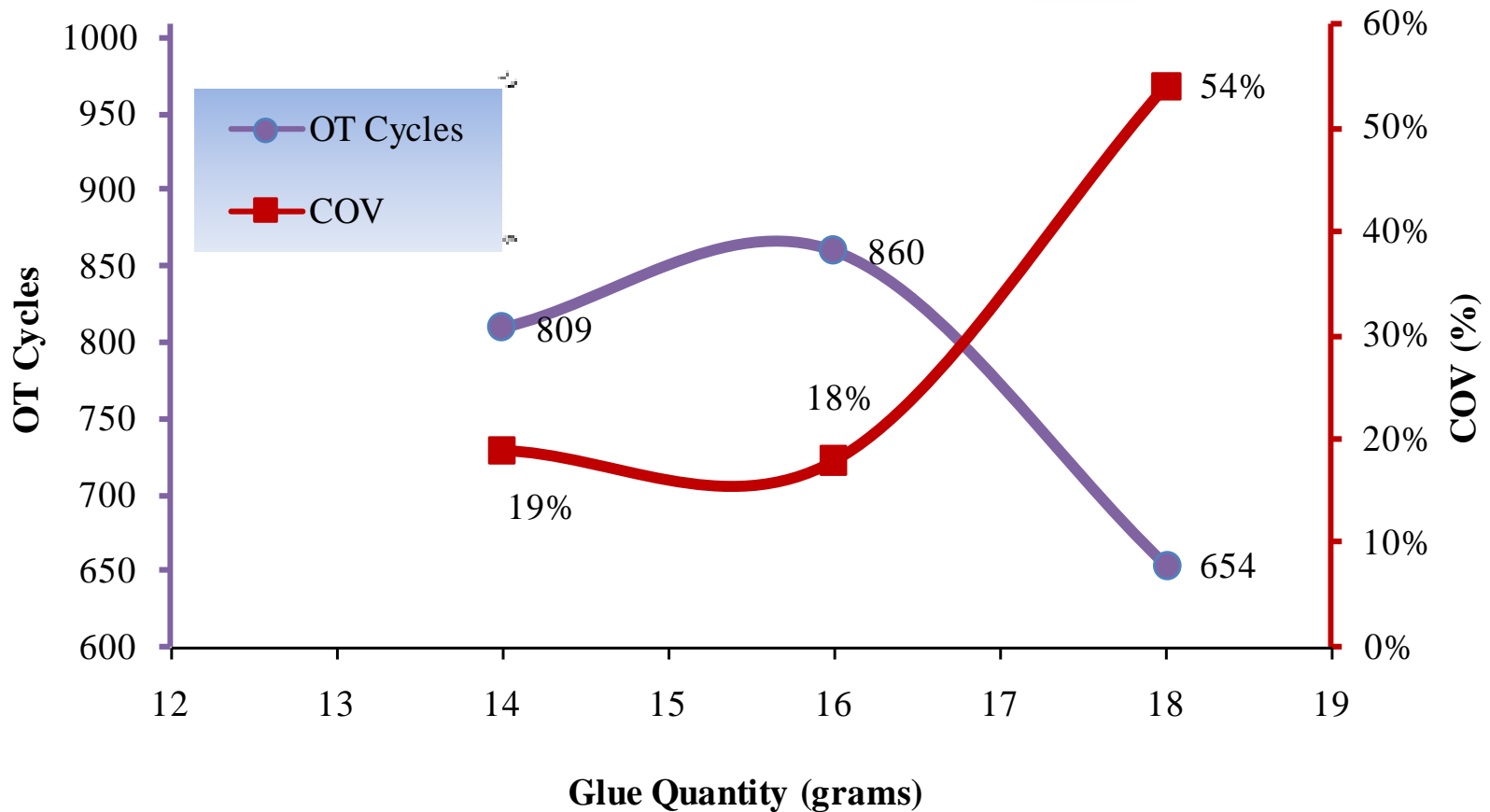
Bryan CAM (FM 158)
 (6.7% PG 76-22 + Limestone+ 1% Lime)

Plant-mix – 5 Replicates
Two-part 2 ton epoxy resin



Task 2-2-8: Glue Quantity...

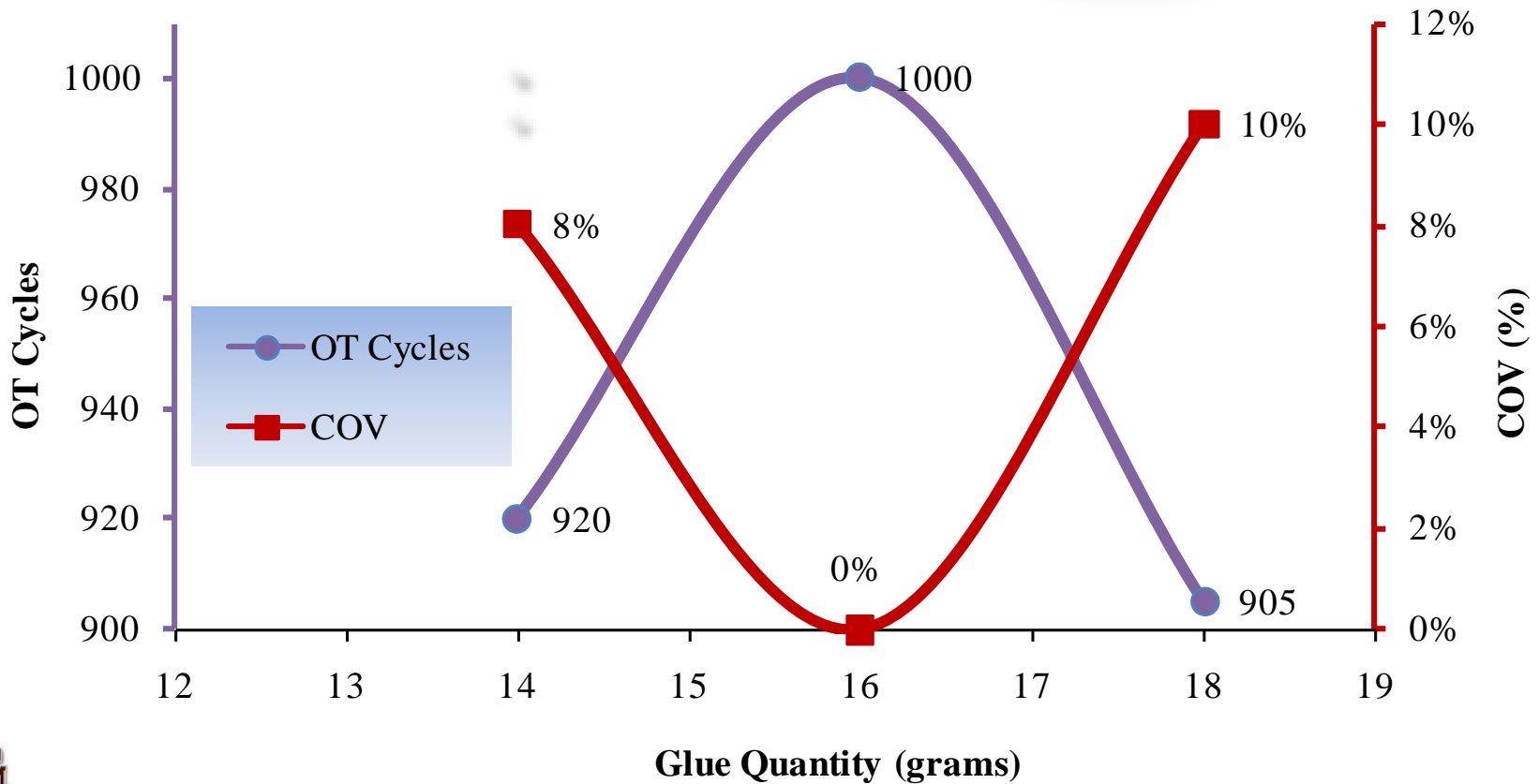
Bryan CAM (FM 158)
 (6.7% PG 76-22 + Limestone+ 1% Lime)
 5 Replicates
 Two-part 2 ton epoxy resin



Task 2-2-8: Glue Quantity...

Bryan CAM (FM 158)
(6.7% PG 76-22 + Limestone+ 1% Lime)

Best 3 Replicates out of 5
Two-part 2 ton epoxy resin



Task 2-2-8: Glue Quantity....

Analysis & Summary

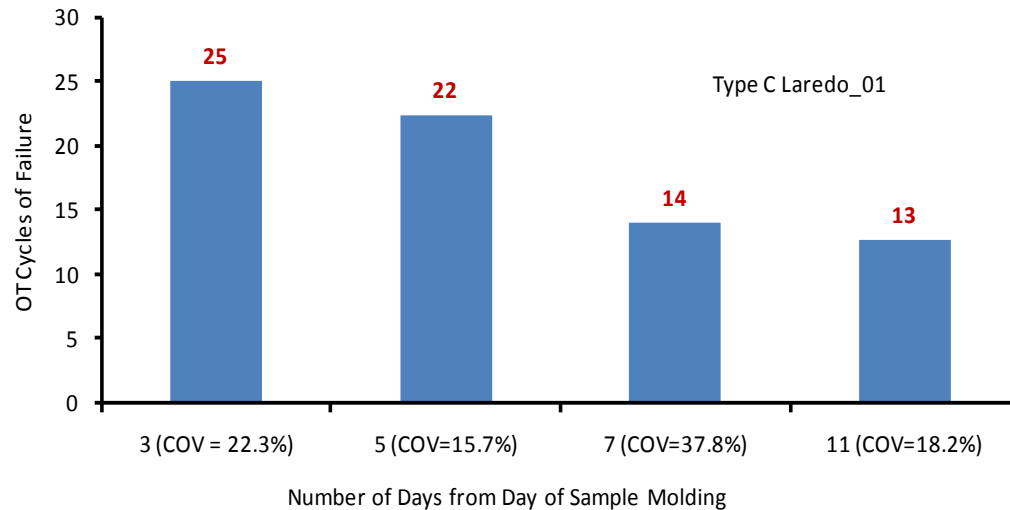
- Peak load appears to be increasing with glue quantity
- 18 g → high COV(>30%), spillage, wastage, etc
- 16 g → consistent results with lowest COV; OT cycles highest for 16 g
- 14 g → too little
- 2-part 2-ton epoxy & high strength OKAY; putty → workability problems
- Proposal → Use 16 g of the 2-Part 2-ton epoxy per OT sample for old plates
- Other glue types!!

Tex-248-F Item 5.3.3

- Consider modifying as follows:

“Glue the specimens individually and use 16 ± 0.5 grams (16 ± 0.5 mls or 2/3) of the 2-Part 2-ton epoxy resin per specimen. Cover the majority of both the base plates with the epoxy including the tape, teflon, or metal strip. Secondly, apply some glue, about 3 grams (remaining from the 16 ± 0.5 g) to the specimen surface that will be attached to the base plates. Glue the trimmed specimen to the base plates. “

Task 2-2-1: Sample Sitting Time.

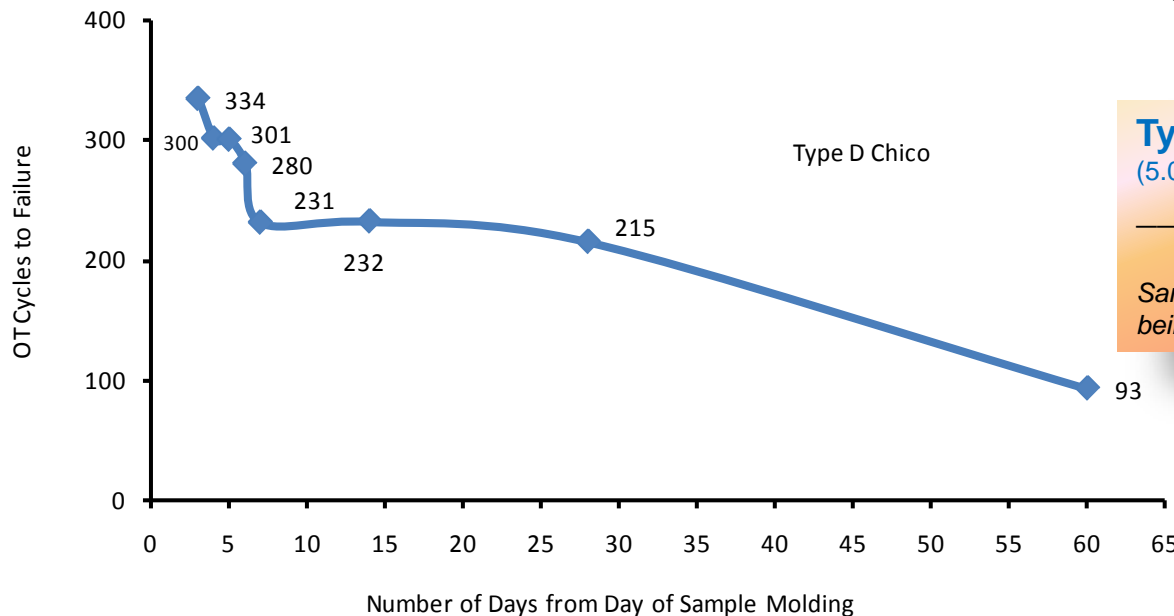


Type C Laredo

(5.0% PG 64-22 + Gravel + 1% Lime + 20% RAP) - PM

Samples left at room temperature while glued to the OT plates

OT cycles decreasing with sitting time???



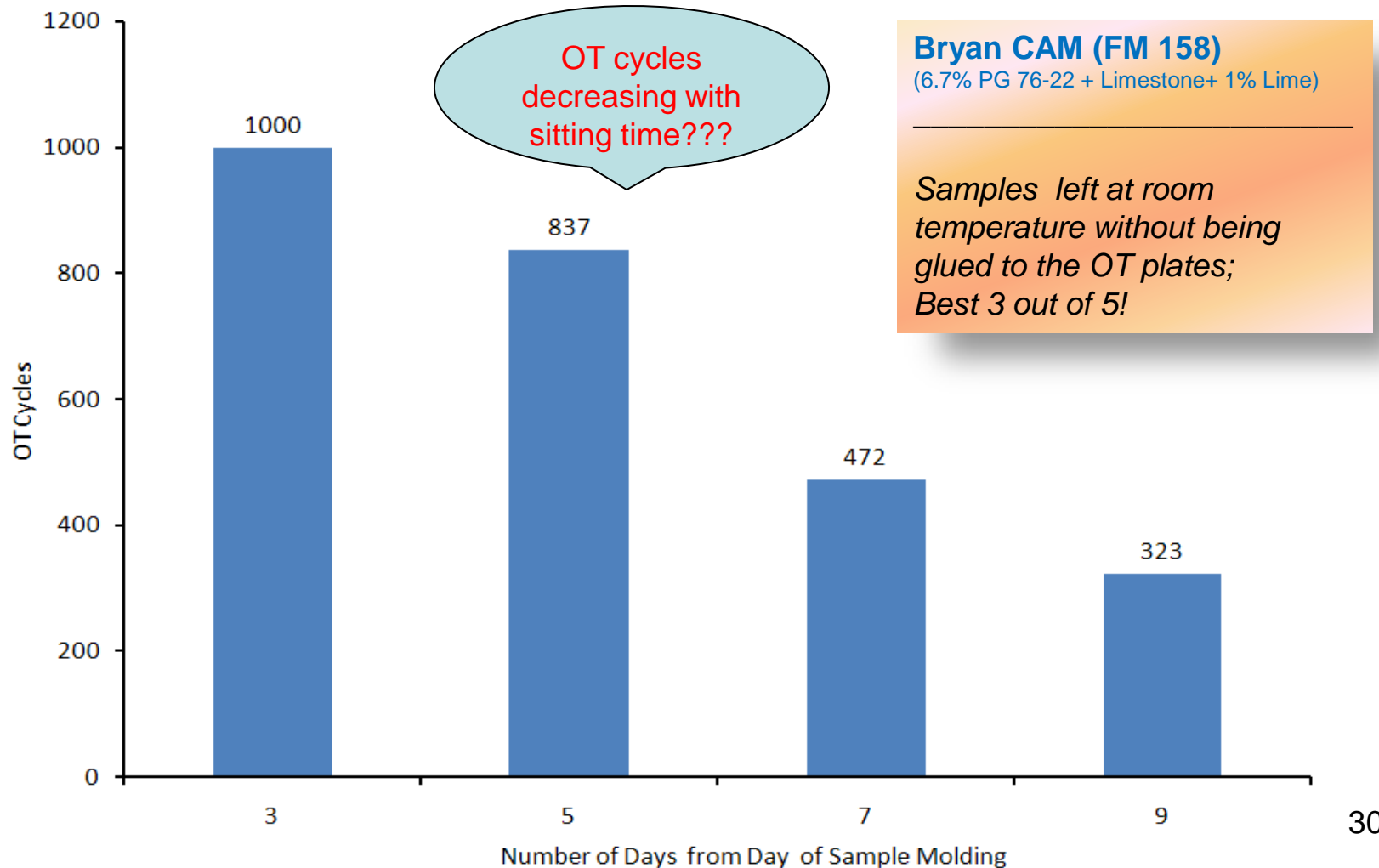
Type D Chico

(5.0% PG 70-22 + Limestone)

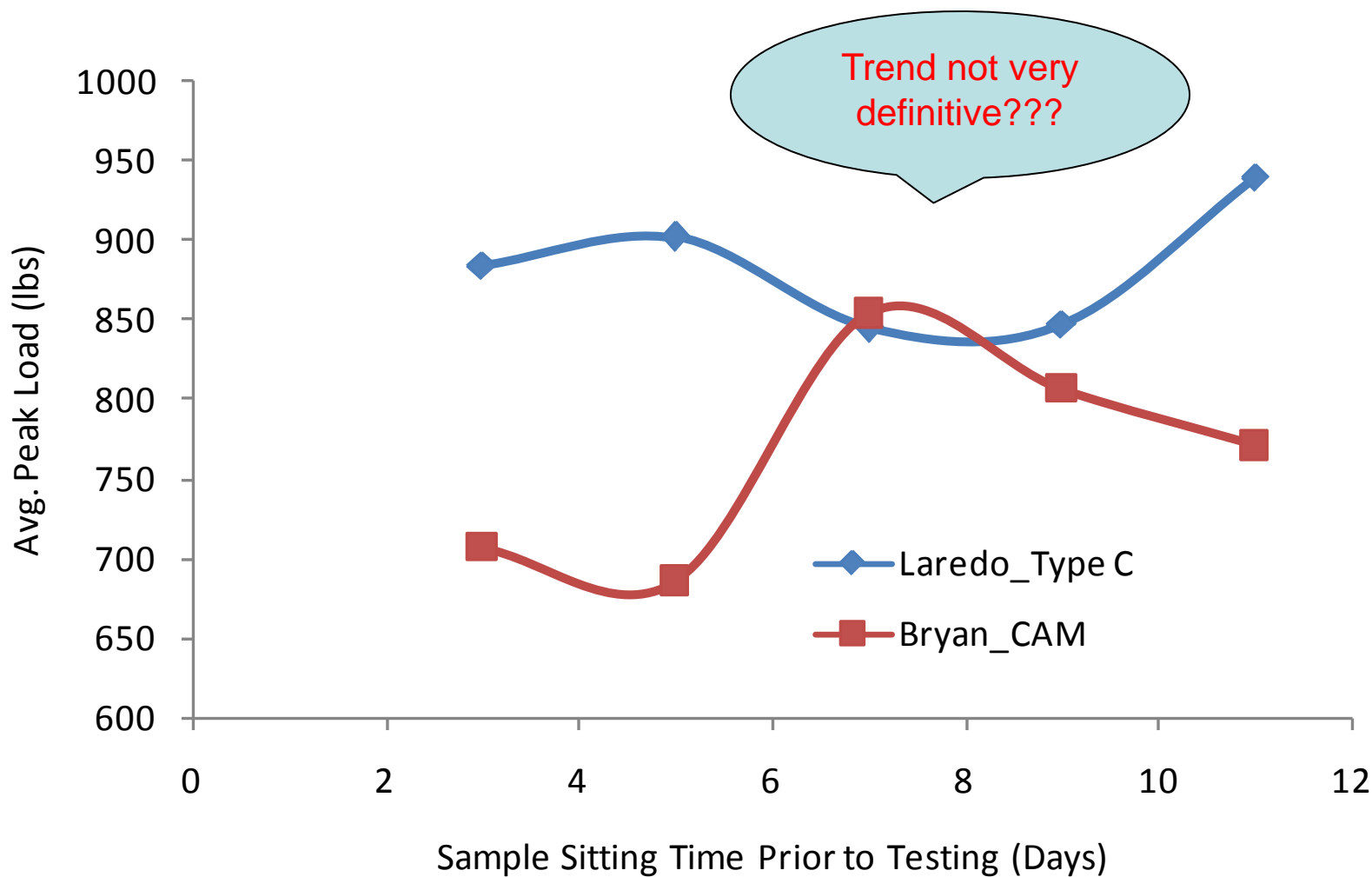
Samples left at room temperature without being glued to the OT plates

Best 3 out of 5!!

Task 2-2-1: Sample Sitting Time..

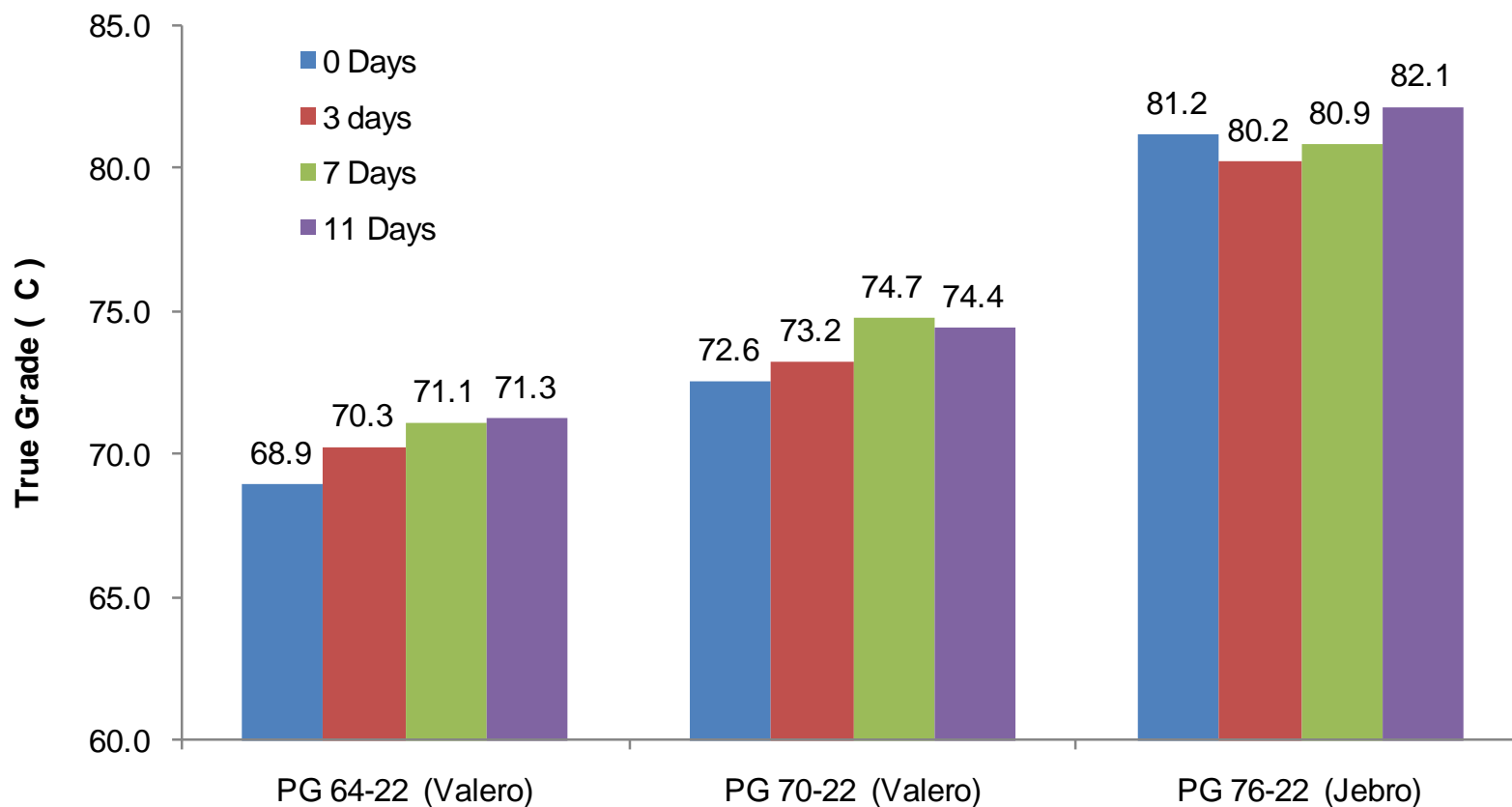


Task 2-2-1: Sample Sitting Time...



Task 2-2-1: Sitting Time....

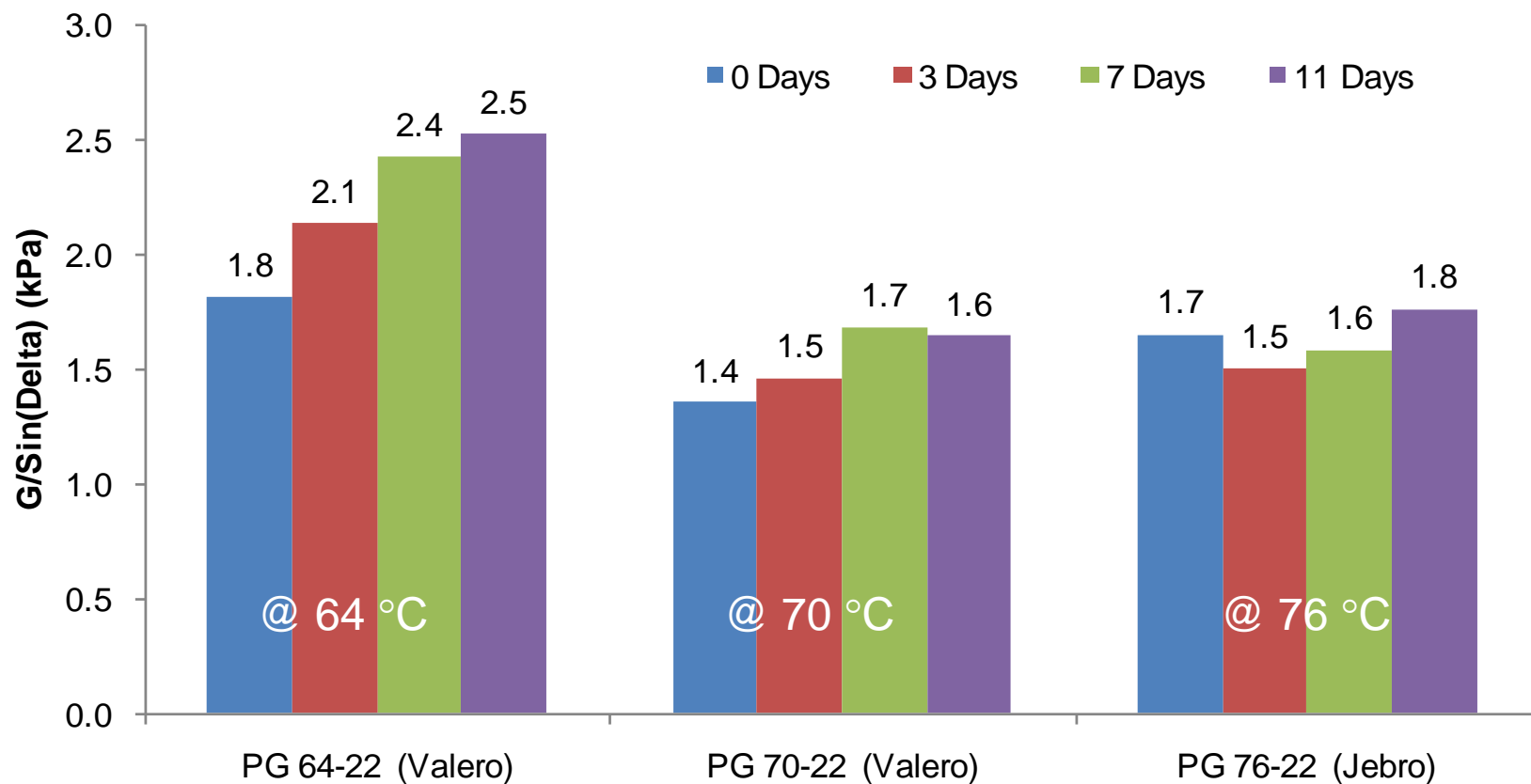
Asphalt-binder: True high temperature PG grade



Asphalt-Binders: Subjected to same heating & sitting conditions as for OT samples

Task 2-2-1: Sitting Time....

Asphalt-binder: Complex modulus & phase angle



Task 2-2-1: Mixed Sitting Time....

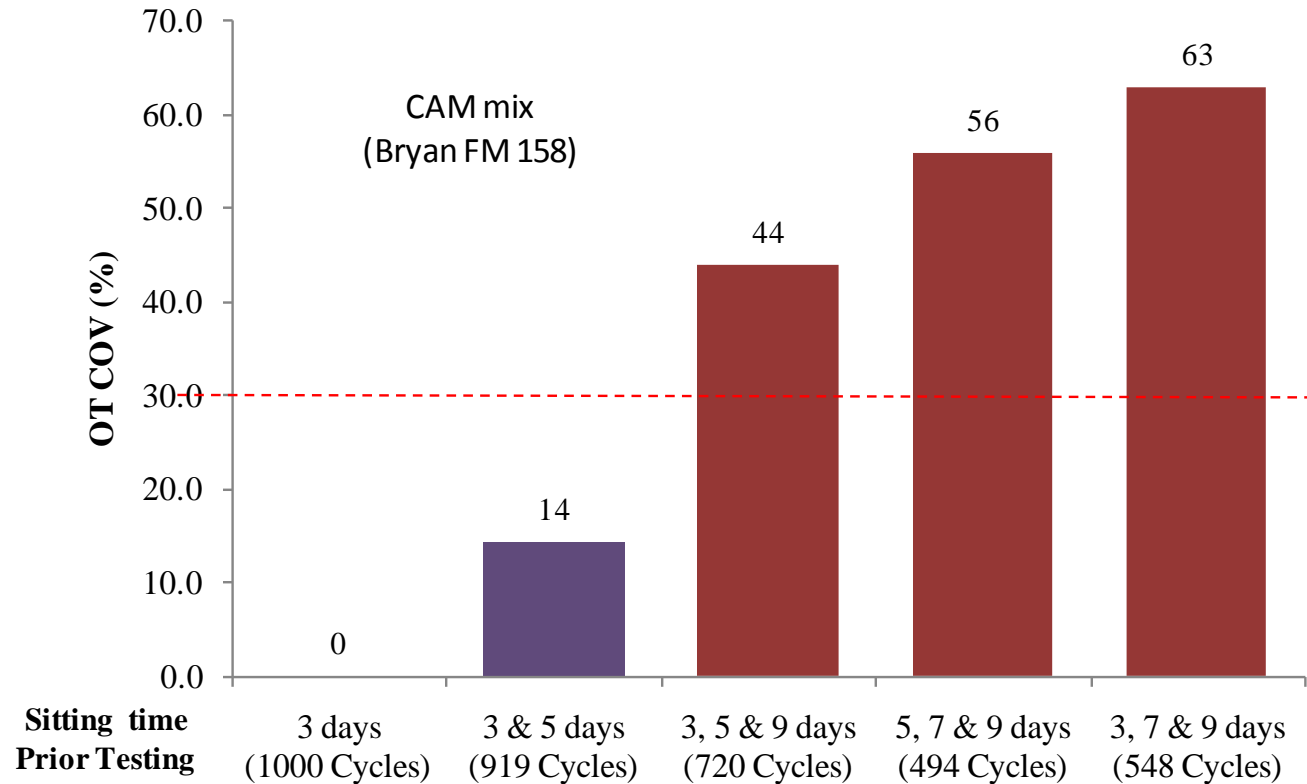
Bryan CAM (FM 158)
 (6.7% PG 76-22 + Limestone+
 1% Lime)

Samples left at room temperature without being glued to the OT plates

Legend:

3 days – means all samples were tested within 3 days of molding

3 & 5 days – means some samples were tested on day 3 while other samples were tested on day 5, and the results averaged



Task 2-2-1: Mixed Sitting Time.....

Laredo Type C

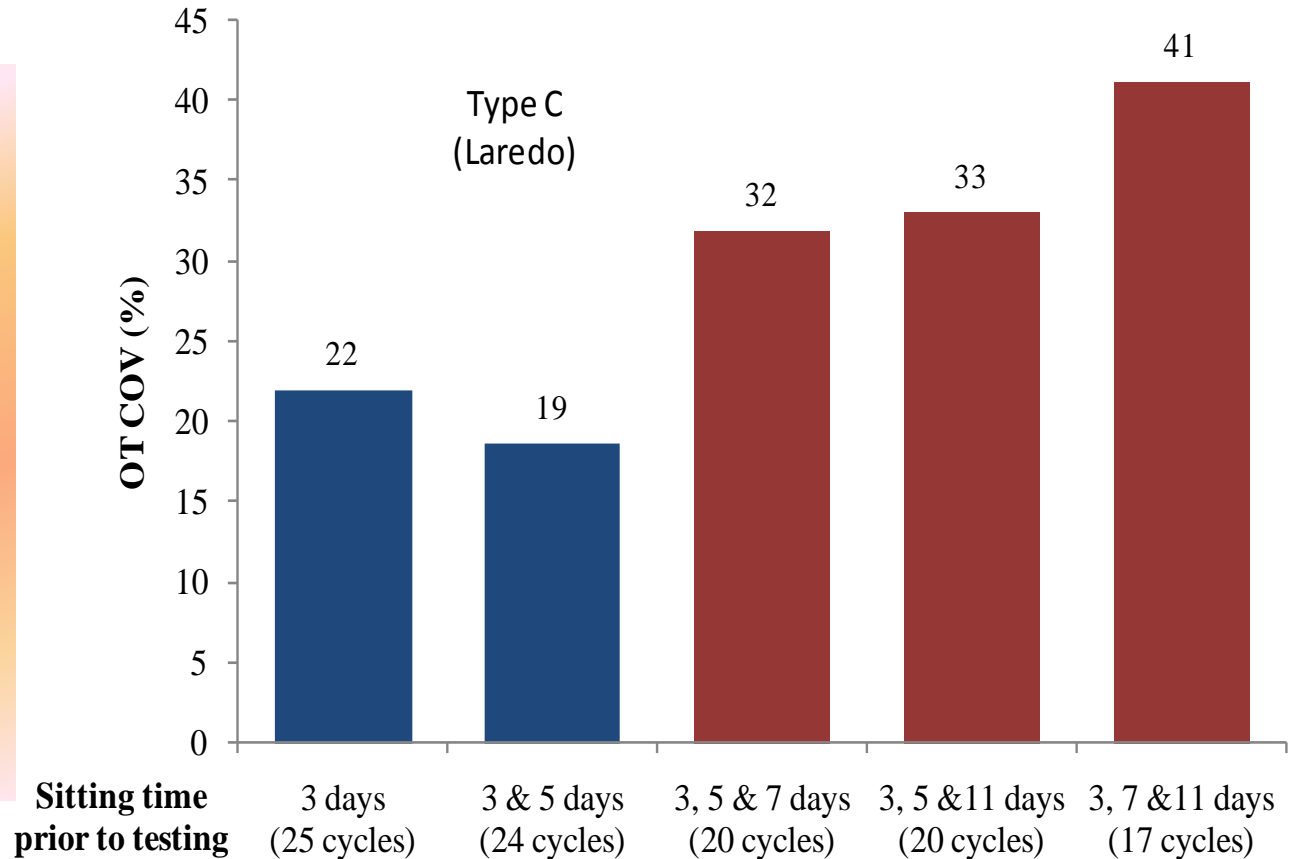
(5.0% PG 64-22 + Gravel + 1% Lime + 20% RAP) - PM

Samples left at room temperature without being glued to the OT plates

Legend:

3 days – means all samples were tested within 3 days of molding

3 & 5 days – means some samples were tested on day 3 while other samples were tested on day 5, and the results averaged



Task 2-2-1: Sample Sitting Time.....

Analysis & Summary

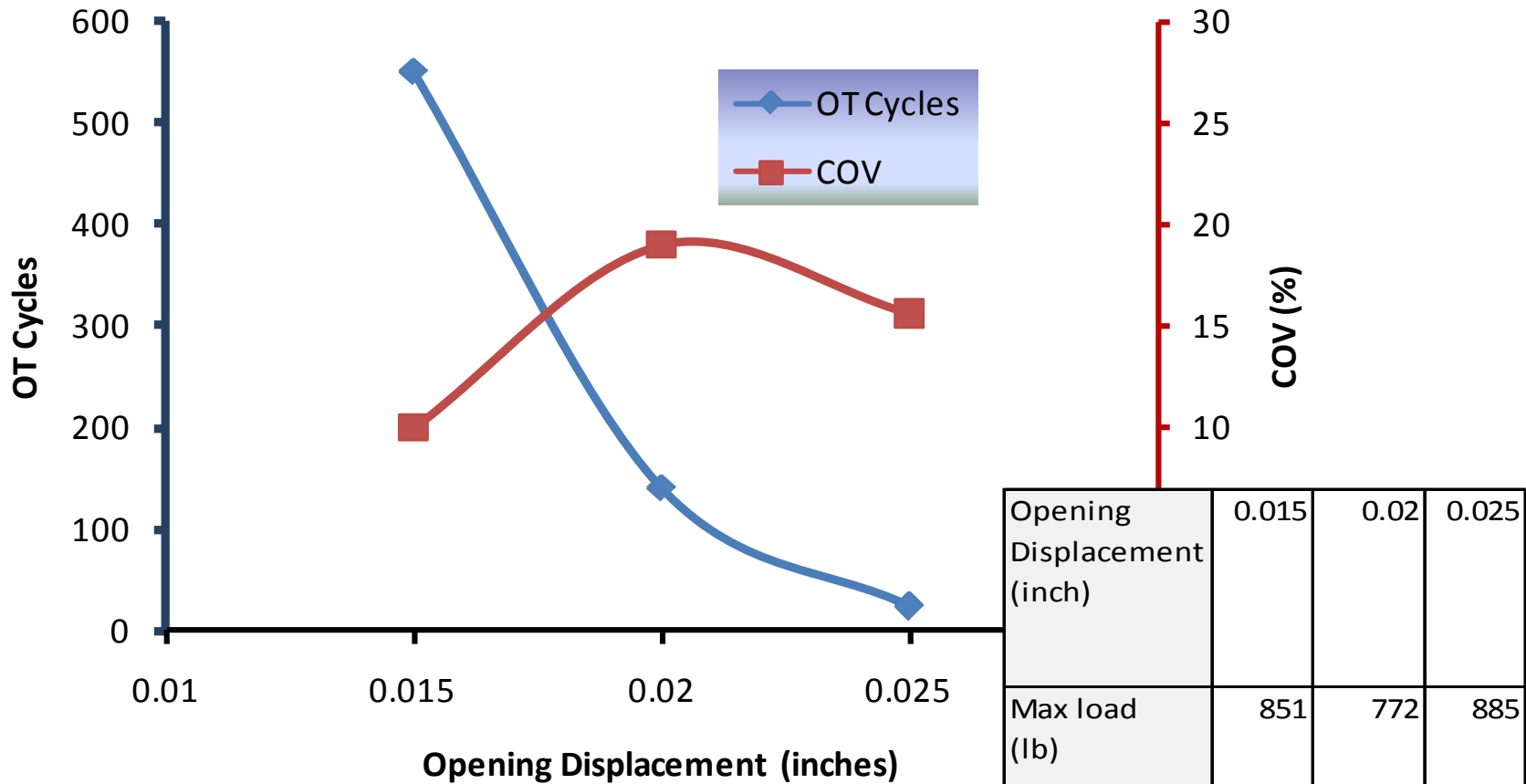
- No significant change in OT cycles for up to 5 days
- Significant decrease in OT cycles beyond 5 days
- Trend not very definitive for the relationship between P_{max} & sample sitting time
- OT cycles & variability → reasonable for mixed sitting times of 3 & 5 days.
- Proposal → test within 5 days from day of molding, & once testing has started, similar replicates should preferably be completed within 48 hrs!

Tex-248-F Item 4.1

- Consider adding “Note 2” as follows:

“Note 2 – It is recommended that the specimens be tested within 5 days from the day of molding. And once testing has started, similar replicates should preferably be completed within 48 hrs. Otherwise, the time period from the day of molding to the day of actual testing each specimen should be recorded and reported as part of the results“

Task 2-2-9: Test Parameters.



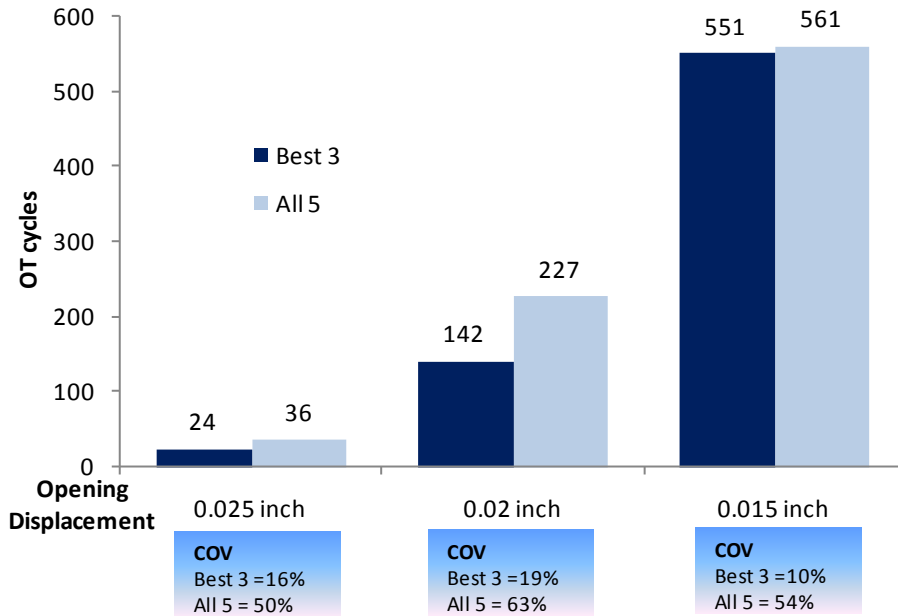
Opening Displacement (inch)	0.015	0.02	0.025
Max load (lb)	851	772	885
COV (%)	28%	7%	3%

Laredo Type C – Plant mix
 (5.0% PG 64-22 + Gravel + 1% Lime + 20% RAP)

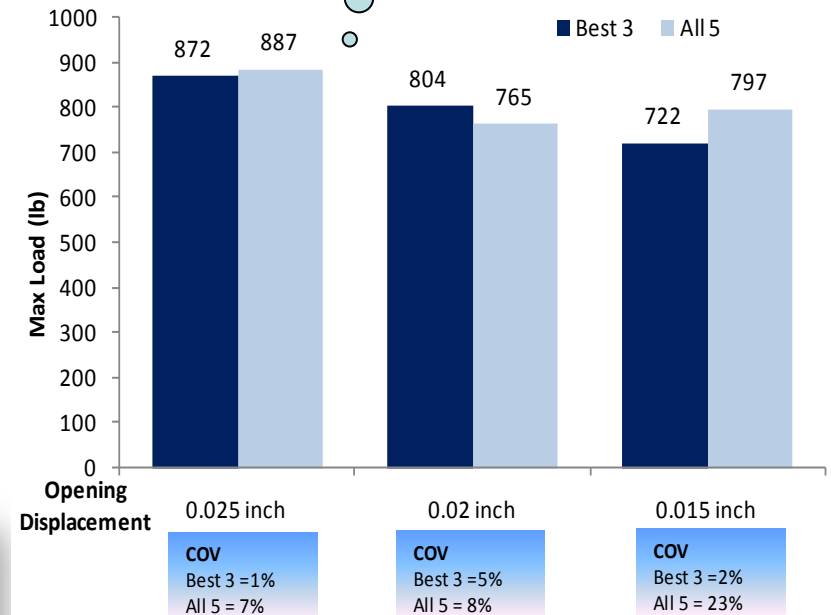
Best 3 out of 5



Task 2-2-9: Test Parameters..



Compared to OT cycles, OT peak load appears to be less sensitive to changes in loading rate!!!



Laredo Type C – Plant mix
(5.0% PG 64-22 + Gravel + 1% Lime + 20% RAP)

Best 3 out of 5



Task 2-2-9: Test Parameters...

Analysis & Summary

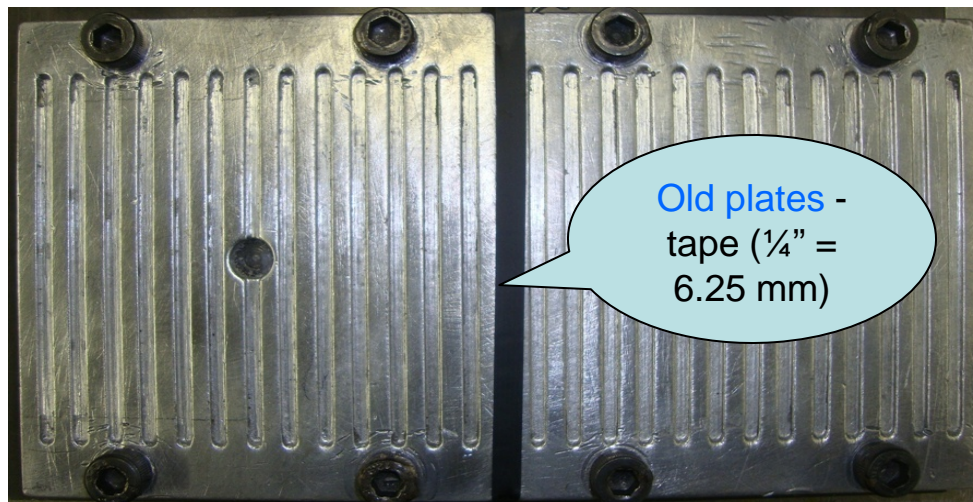
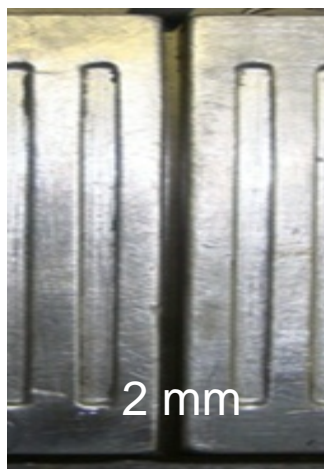
- No significant change in peak load with changing loading rate.
- OT cycles increases with decrease in opening displacement
- No definitive trend for change in COV; but lowest for 0.015 inches
- No definitive relationship for P_{max} , but COV is lowest for 0.025 inches
- Reducing loading rate may erroneously pass mixes; consider different loading rates for different mixes & location in PVMNT structure
- [Proposal](#) → No change.

Tex-248-F Items 2.1 & 5.7

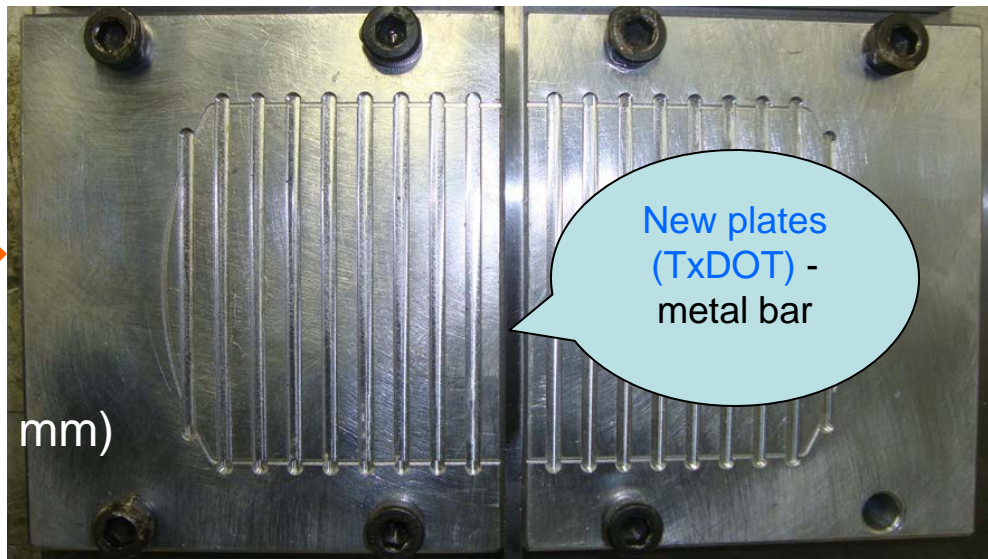
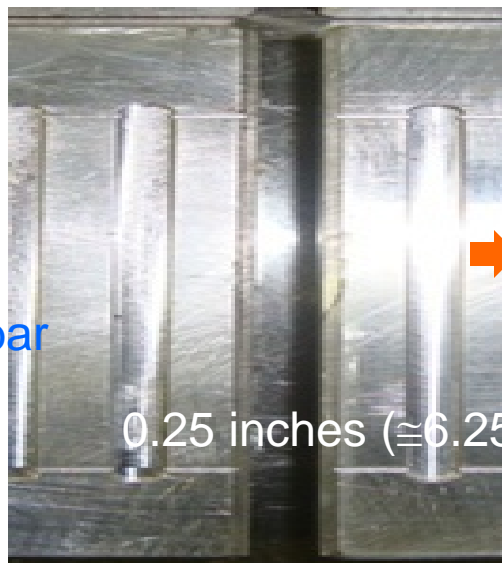
- Stay with current test parameters!

Task 2-2-7: Gap Width ($\frac{1}{4}$ Inch).

1
Tape

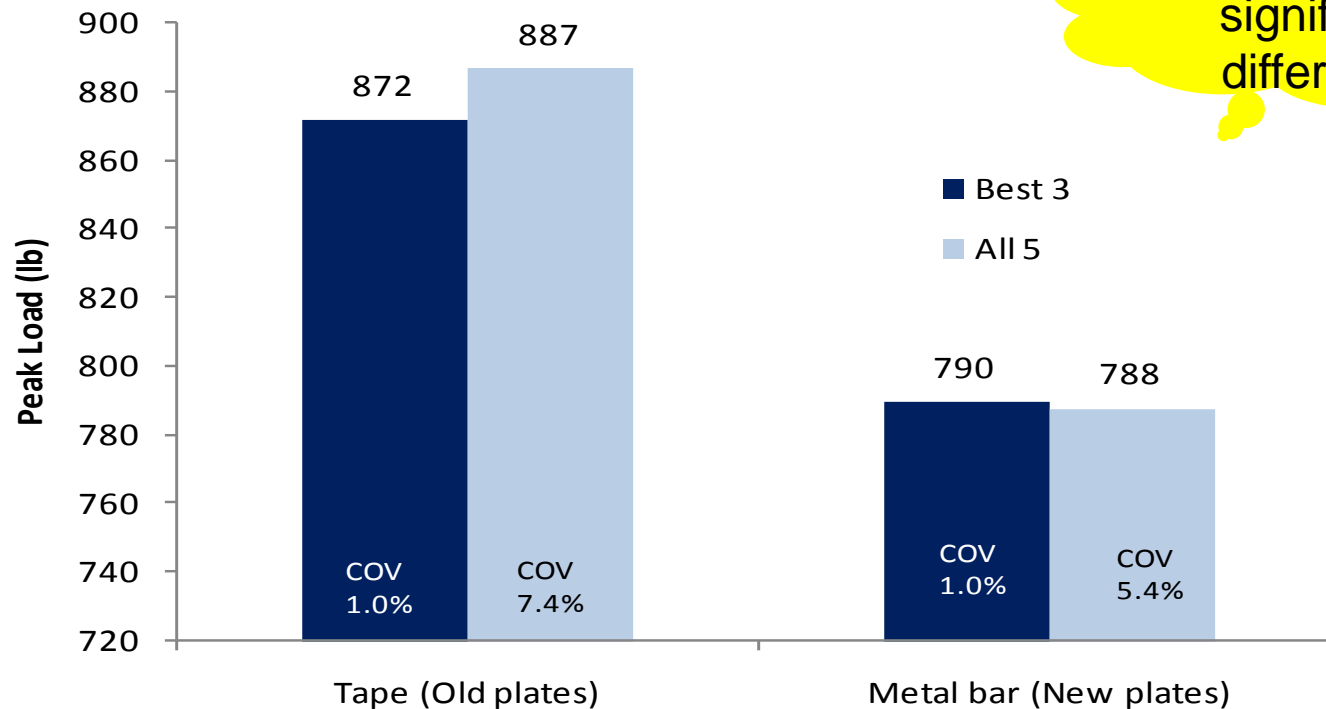


2
Metal bar



Task 2-2-7: Gap Width..

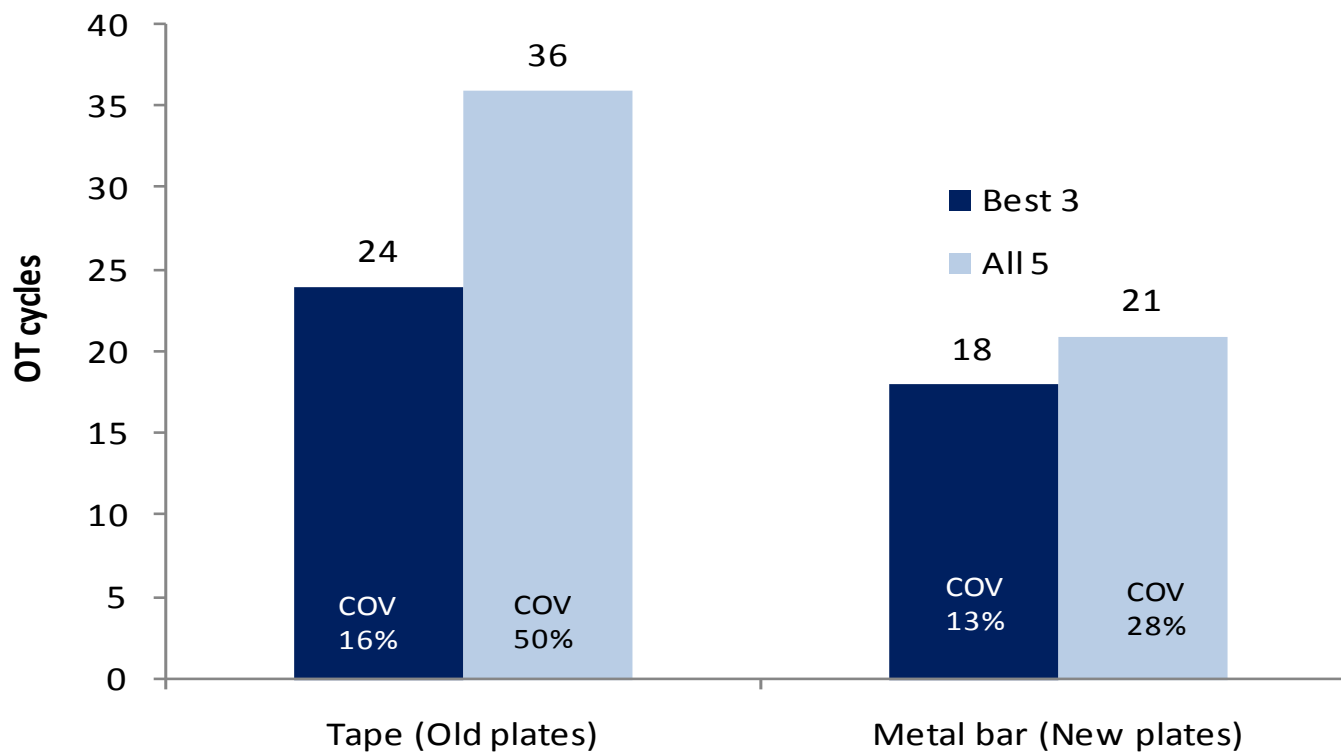
Comparison of Peak Loads & COV



No major significant difference

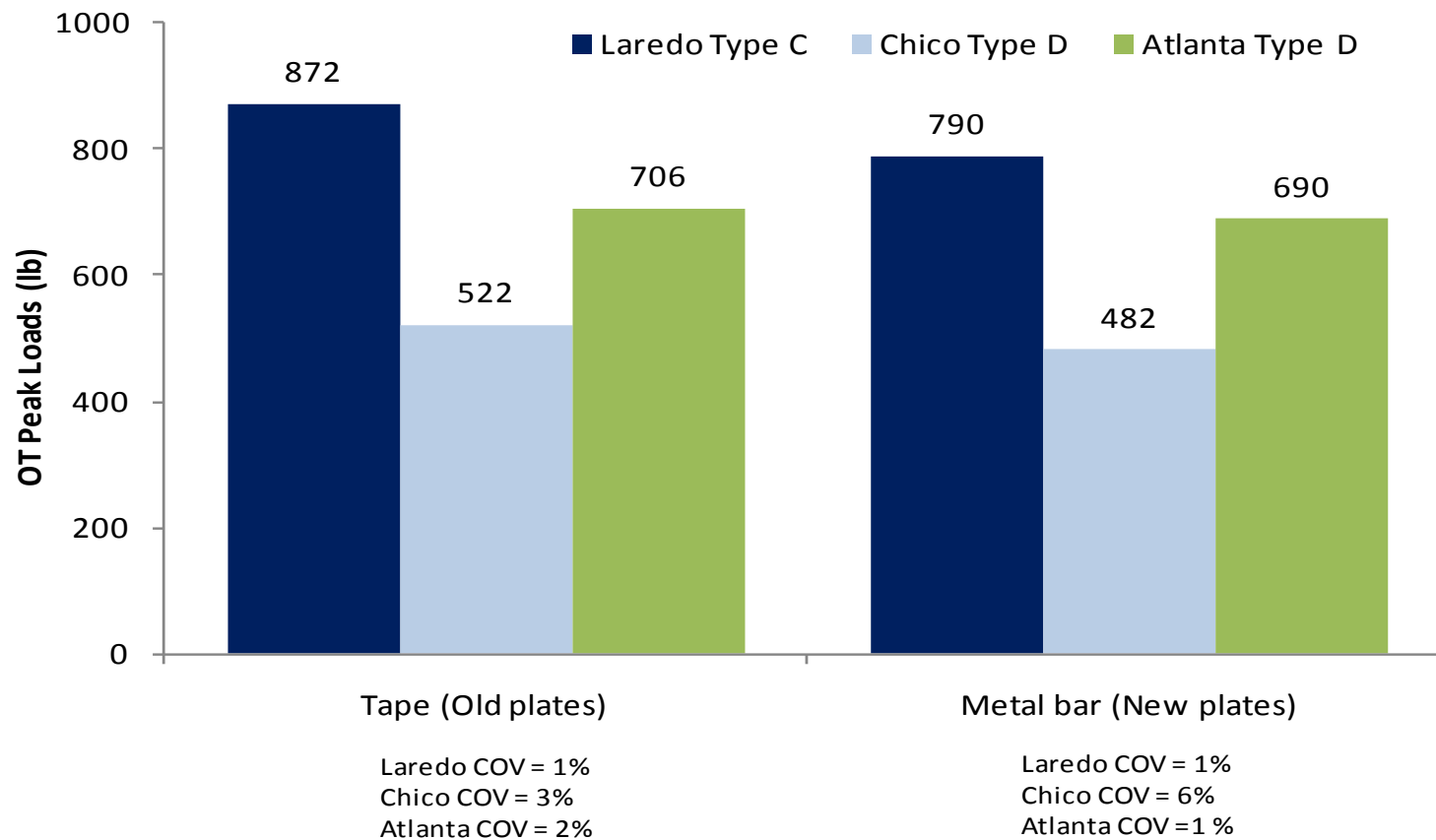
Task 2-2-7: Gap Width...

Comparison of Number of OT Cycles & COV



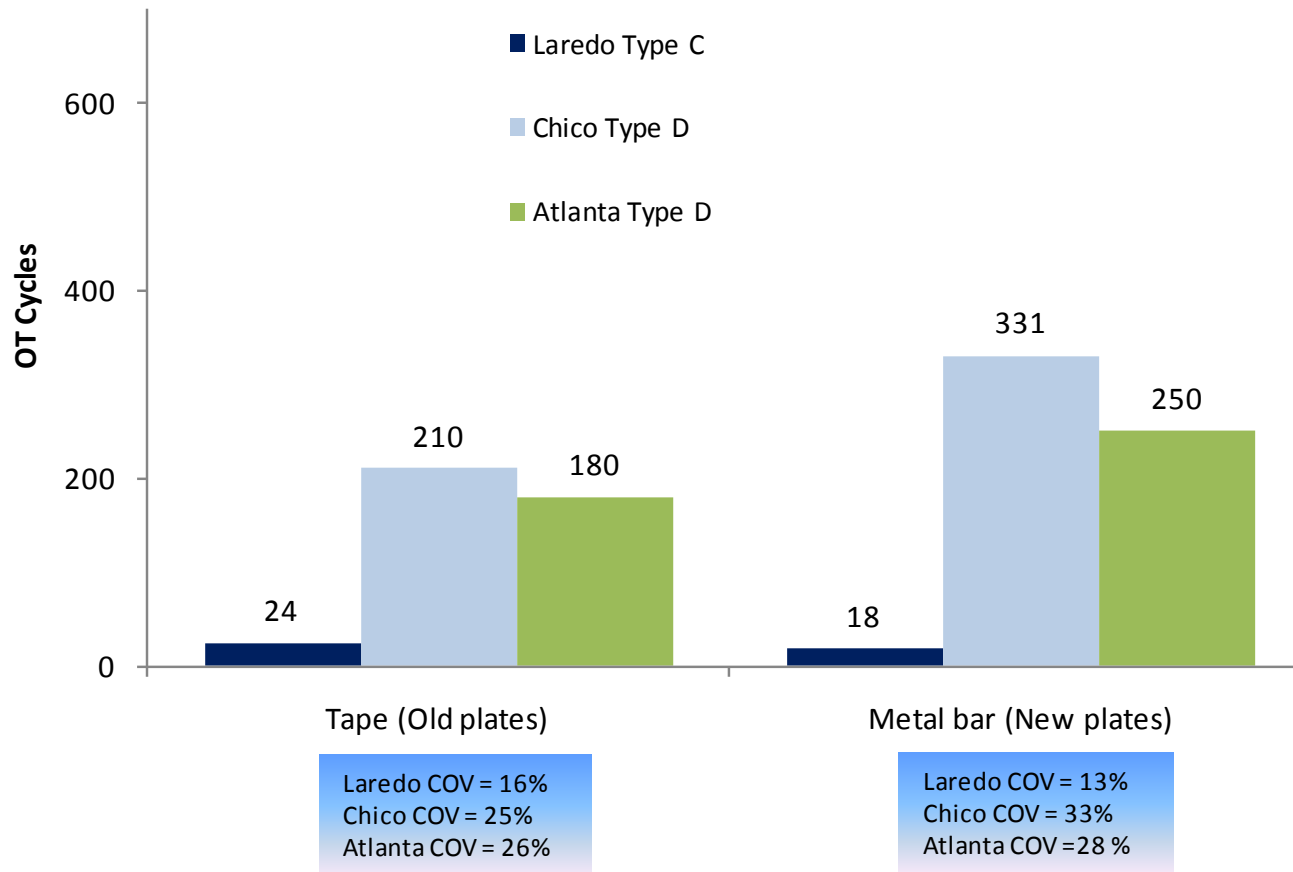
Task 2-2-7: Gap Width...

Comparison of OT Peak Load & COV



Task 2-2-7: Gap Width...

Comparison of Number of OT Cycles & COV



Task 2-2-7: Old vs. New Plates

All Oven dried – **all tape**

Laredo Type C – raw aggregates

Plate Type	Chico Type D		Atlanta Type D		Laredo Type C	
	Peak Load (lb)	OT cycles	Peak Load (lb)	OT cycles	Peak Load (lb)	OT cycles
Old Plates	516 (1%)	210 (25%)	706 (2%)	180 (26%)	618 (2%)	24 (16%)
New Plates with New Baseplates	623 (5%)	55 (14%)	721 (4%)	102 (7%)	622 (4%)	40 (36%)

*COV Values in parenthesis

New plates
Low variability
except for
Laredo

Task 2-2-7: Gap Width.....

Analysis & Summary

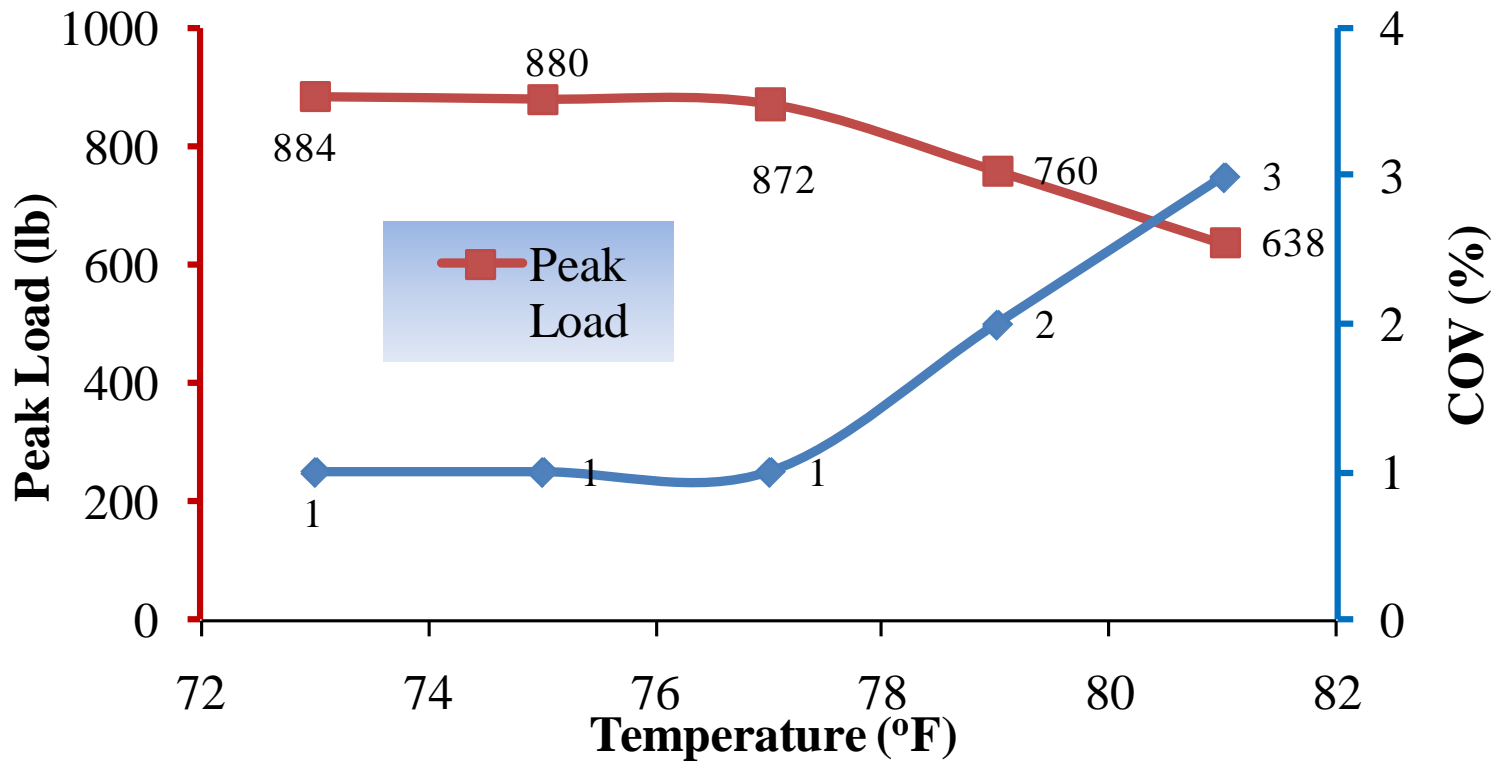
- No significant change in peak load for either arrangements.
- No definitive trend in change of OT cycles and COV
- New plates \Rightarrow very user friendly; easy to apply glue & align specimen
- Metal bars – issues pulling out
- Proposal \rightarrow Shift to TxDOT new plates; with caution on use of metal bar!

Tex-248-F Item 3.3

- Consider using New Plates, but be careful with use of metal bars

Task 2-2-5: Test Temp. Differential

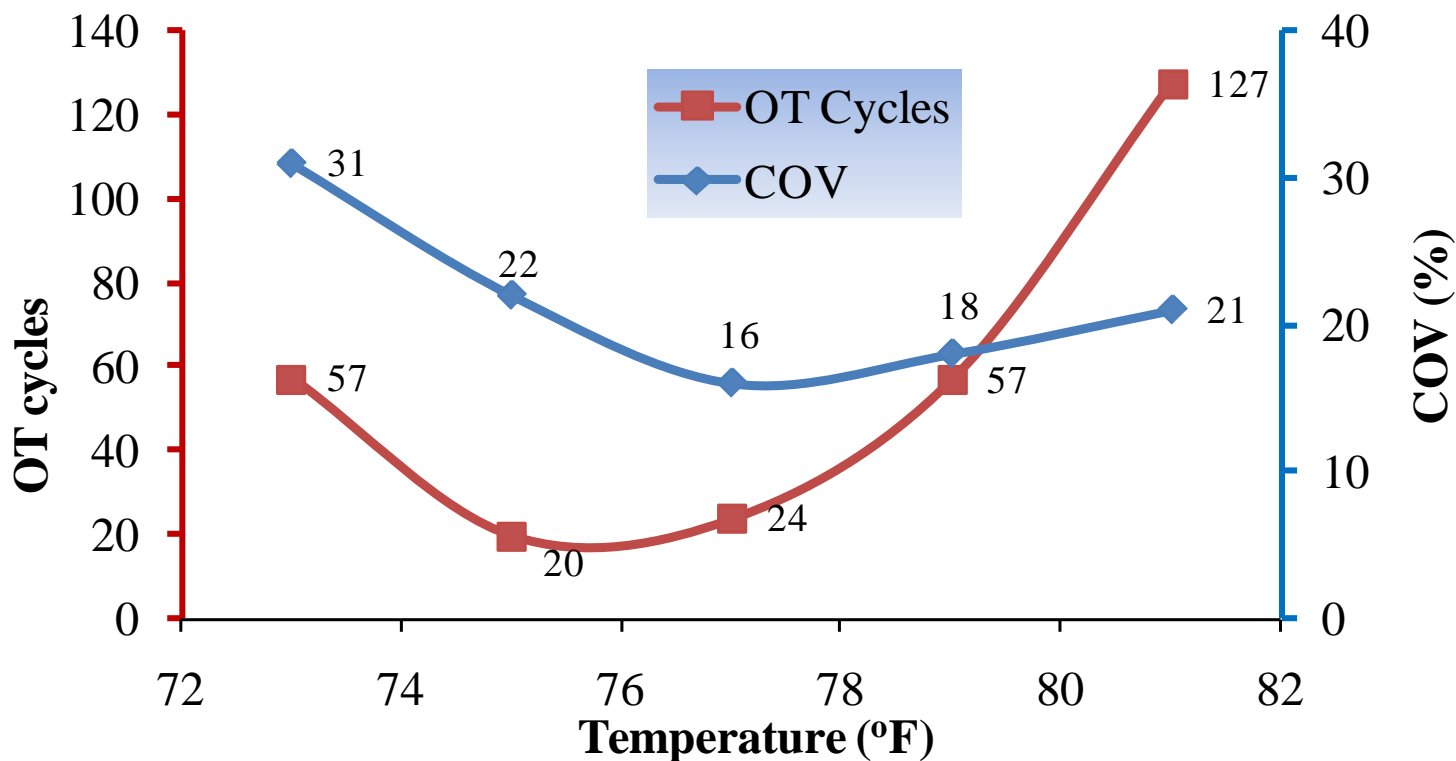
Comparison of Effects of Test Temperature: 73-81 °F
OT Peak Load Vs Temperature



Laredo Type C: (5.0% PG 64-22 + Gravel + 1% Lime + 20% RAP)

Task 2-2-5: Test Temp. Differential

Comparison of Effects of Test Temperature: 73-81 °F
OT Cycles Vs Temperature

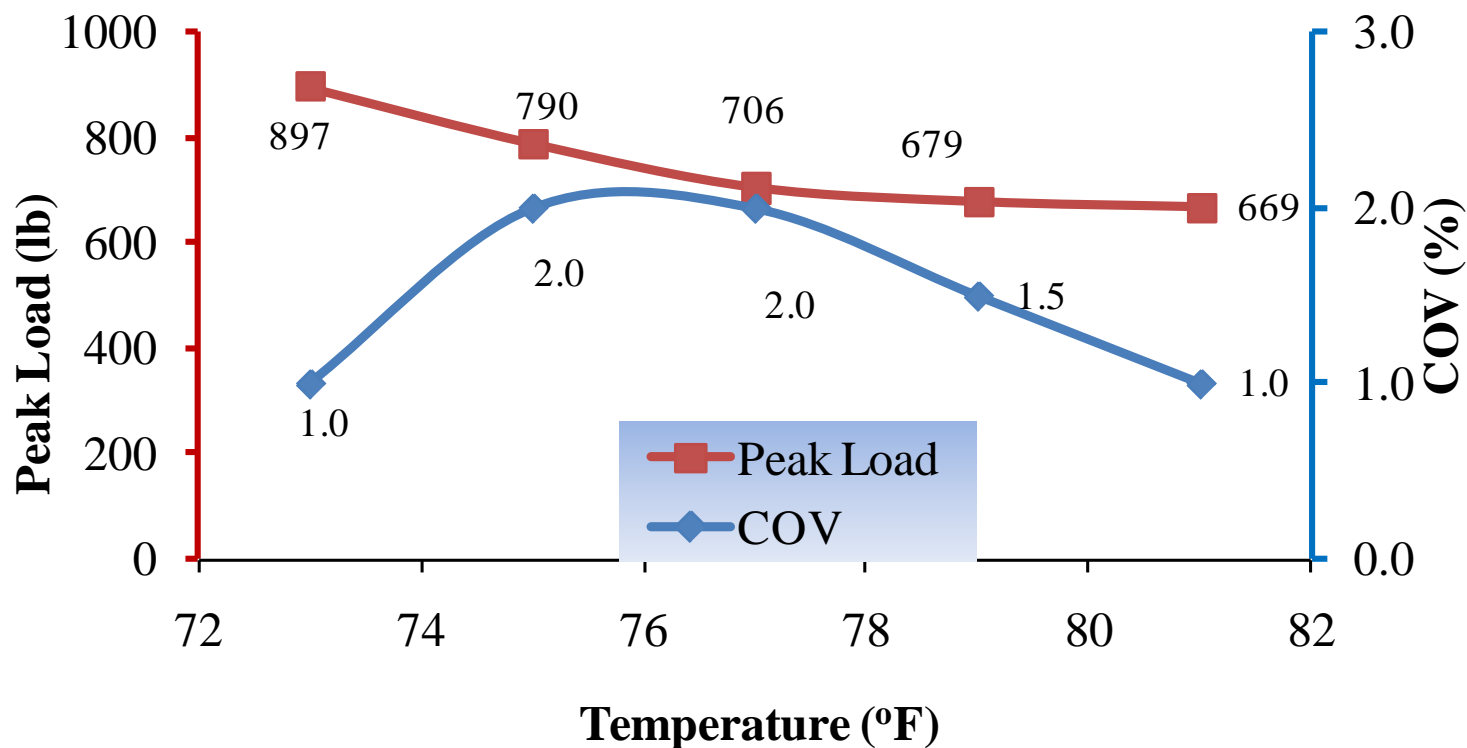


Laredo Type C: (5.0% PG 64-22 + Gravel + 1% Lime + 20% RAP)

Task 2-2-5: Test Temp. Differential

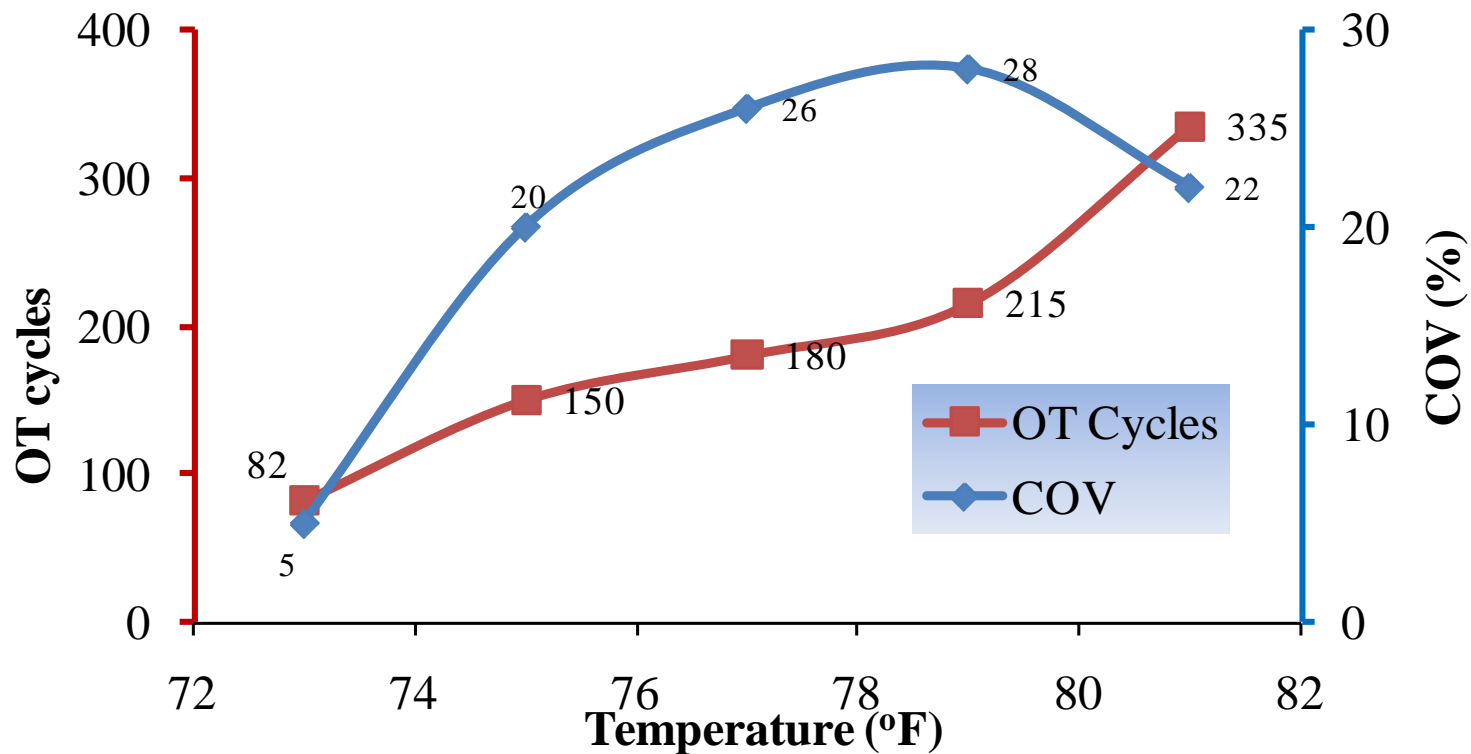
Comparison of Effects of Test Temperature: 73-81 °F

OT Peak Load Vs Temperature



Task 2-2-5: Test Temp. Differential

Comparison of Effects of Test Temperature: 73-81 °F
OT Cycles Vs Temperature



Task 2-2-5: Test Temp. Differential

Analysis & Summary

- Peak load decreases with increase in temperature
- OT cycles → increasing trend with increase in temperature; change very significant for temperature differential of ± 2 °F
- COV → No definitive trend
- Proposal → For any target test temperature, use ± 2 °F as maximum tolerance limit

Tex-248-F Item 5.7.1

- No change; maintain current temperature & tolerance since it is more conservative
- NB: All OT machines set to operate at ± 0.5 °F

End..

Contributions, Questions,
Comments, & Discussions!!!