Quality.Together

SPIB Technical Committee
June 19, 2015

Update on Southern Pine Design Values

History

- Original IGT Published: 1991
- Monitoring: 1994-2010
- Destructive Testing: 2011
  - #2 2x4
  - MOE, MOR, UTS
- Significant decreases observed

2012

- Reduced 2x4 #2 & lower design values
- Conducted New IGT
  - 2 grades, 3 sizes
  - MOE, MOR, UTS, UCS

2013-2015

- New design values published

- Monitoring:
  - #1 2x6 MOR in 2013
  - #2 2x4 MOR in 2014
  - #2 2x4 UTS in 2015

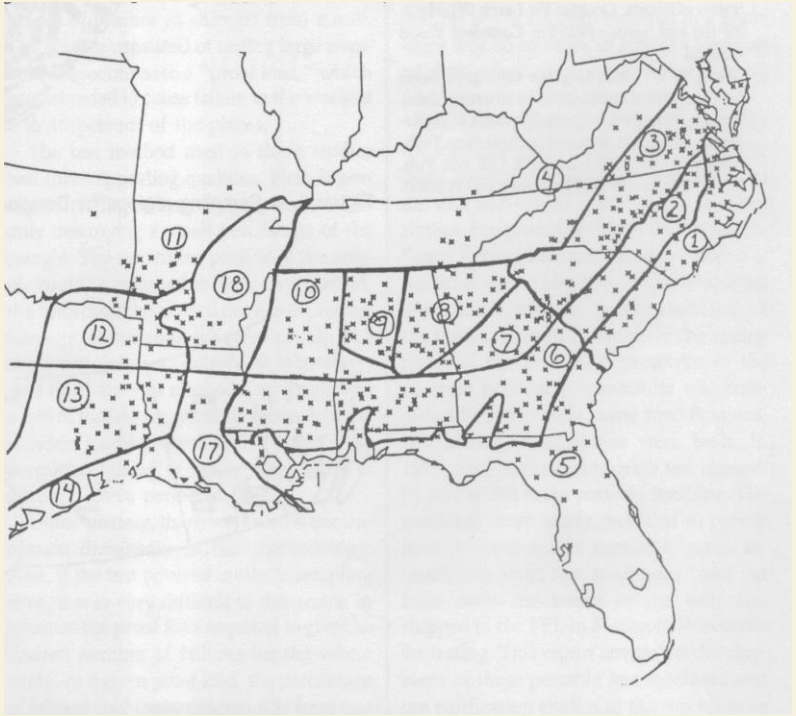
InGrade Testing Protocol

- Test 2 grades, in each of 3 sizes
- Nondestructively evaluate stiffness (MOE)
- Destructively test for:
  - Bending Strength (MOR)
  - Tension Strength (UTS)
  - Compression Parallel to Grain (UCS)

Sampling

- Mills assigned to one of 16 homogeneous Southern Pine growing regions
- Includes SPIB and TP mills
- Randomly select mills in proportion to regional production
- Target sample size: 360 pieces per “cell”
- Test 10-12 pieces from each selected mill

Southern Pine Regions



Data Collected

- Grade
- Defect – grade controlling, msrd
- Dimensions – width, thickness, length
- MC
- Temperature
- Growth Characteristics – rpi, %sw

Data Collected

- Bending Tests:
  - 1/3 point loading
  - Defects randomly placed
  - 17:1 span to depth ratio
  - Stiffness (MOE)
  - Strength (MOR)
  - Failure Code

Data Collected

- Tension tests
  - Tested for bending stiffness prior to UTS
  - 8′ gauge length between grips
  - Failure Code

Data Adjustments

- MC adjusted for Temperature
- Properties adjusted to 73 °F if needed (<47°)
- Properties adjusted to 15% MC

Example: for MOR > 2415 psi:

$$MOR_2 = MOR_1 + \frac{(MOR_1 - 2415)}{(40 - MC_1)} * (MC_1 - MC_2)$$

Data Adjustments

- To combine data from different sizes, a “size model” is used to convert all data to a Characteristic Size: 2x8 – 12′

$$F_2 = F_1 * \left(\frac{W_1}{W_2}\right)^w * \left(\frac{L_1}{L_2}\right)^l * \left(\frac{T_1}{T_2}\right)^t$$

Exponents for Size Model

Property	Width, w	Length, l	Thickness, t
MOR, UTS	0.29	0.14	0
UCS	0.13	0	0
MOE	0	0	0

MOE not adjusted for size
No properties adjusted for thickness (applies to dimension lumber only)
Compression values not adjusted for length

Converting 2x4 to 2x8

No.2 2x4, MOR = 3265 psi, 59.5" span

$$MOR_{2x8} = 3265 * \left(\frac{3.5}{7.25}\right)^{0.29} * \left(\frac{59.5}{144}\right)^{0.14}$$

$$MOR_{2x8} = 2336\,psi$$

GQI

- Grade Quality Index – determined from failure code at point of failure.
- Uses ASTM D245 equations to calculate the “strength ratio”
- Based on strength reducing characteristics:
  - Knots
  - Slope of Grain

GQI Check

- D1990 requires a GQI check to ensure that tested material appropriately represents the defects permitted in the grade.
  - SS grade: SR = 0.65
  - #2 grade: SR = 0.45
- *Of pieces for which SR can be calculated*, the 5th percentile must be within +/- 7 points of target

Nonparametric Statistics

- We do not assume a “normal” (or any other) statistical distribution.
- Use “order statistics” to estimate values of interest.
- Permits analysis without actually breaking every piece.

5TH PERCENTILE

- Rank order all data from lowest to highest.
- (5% * sample size) is approximately the order statistic of the 5th percentile "point estimate".
- Example: 100 pieces broken in bending. Use the 5th weakest piece to estimate the 5th percentile.

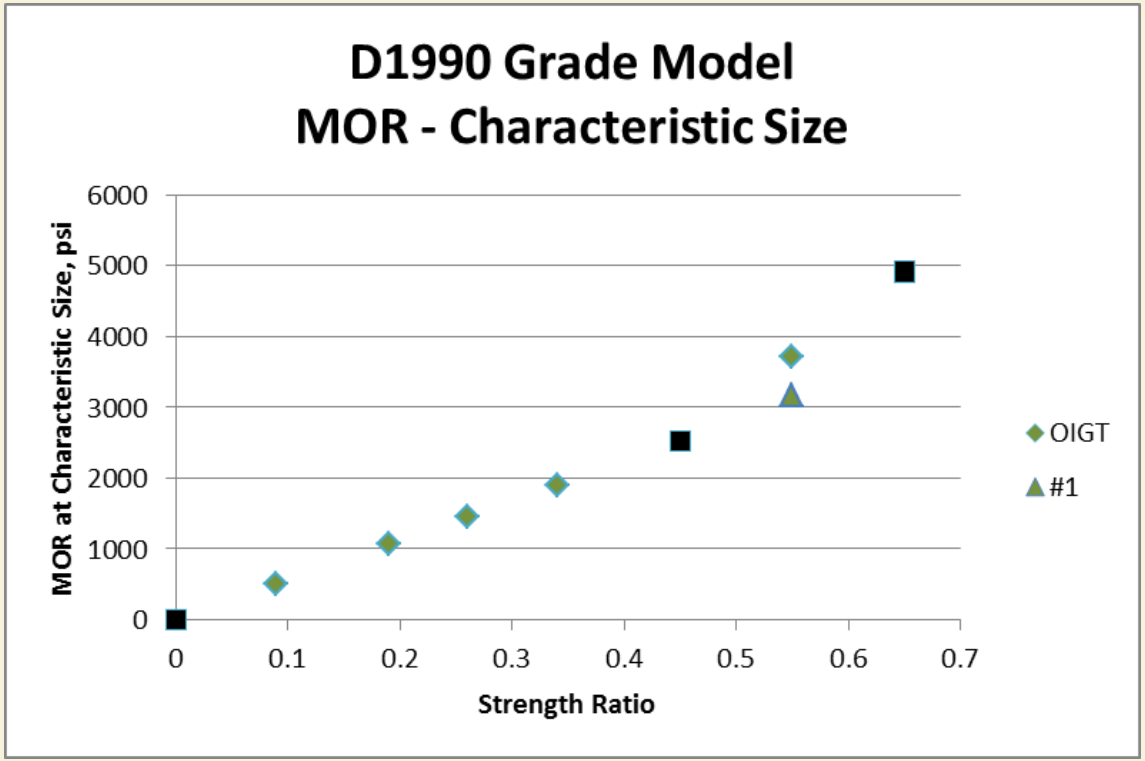
Tolerance Limits

- ASTM D1990 uses the 75% confidence tolerance limit on the 5th percentile.
- Uses data from a piece weaker than actual 5th percentile “point estimate”.
- Provides increased confidence that true 5th percentile is equal to or greater than our estimate.

Grade Model

- Using strength ratios, values for untested grades may be estimated.
- Tested grades:
  - SS with strength ratio of 0.65
  - #2 with strength ratio of 0.45
- Untested Grades:
  - #1 (SR = 0.55), #3 (SR = 0.26), etc.

Grade Model for Original IGT



D1990 Wilcoxon Test

- 2014 revisions to D1990 include a statistical test to compare samples
- Compares the entire distribution – not tails
- Wilcoxon test uses sum of ranks
- Data is combined from two sets and ranked
- Sum of ranks from each set is compared

Wilcoxon Test

Use the sum of the ranks to calculate a Z-value:

$$Z = \frac{\left(SumRank + \frac{1}{2}\right) - \left(m * \left(\frac{N+1}{2}\right)\right)}{\sqrt{\frac{m * n * (N+1)}{12}}}$$

Where m = sample size corresponding to SumRank

n = sample size from other sample

N = total sample size (m + n)

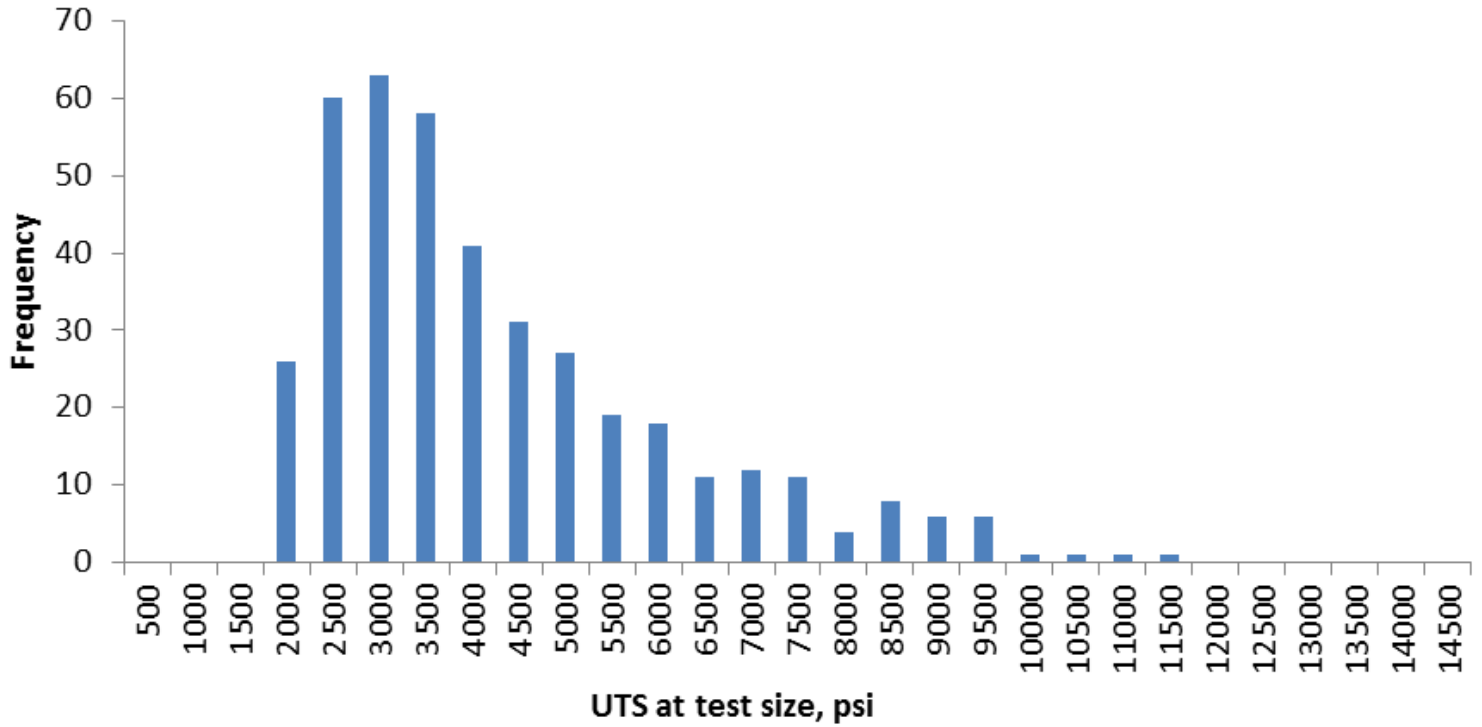
Wilcoxon Results

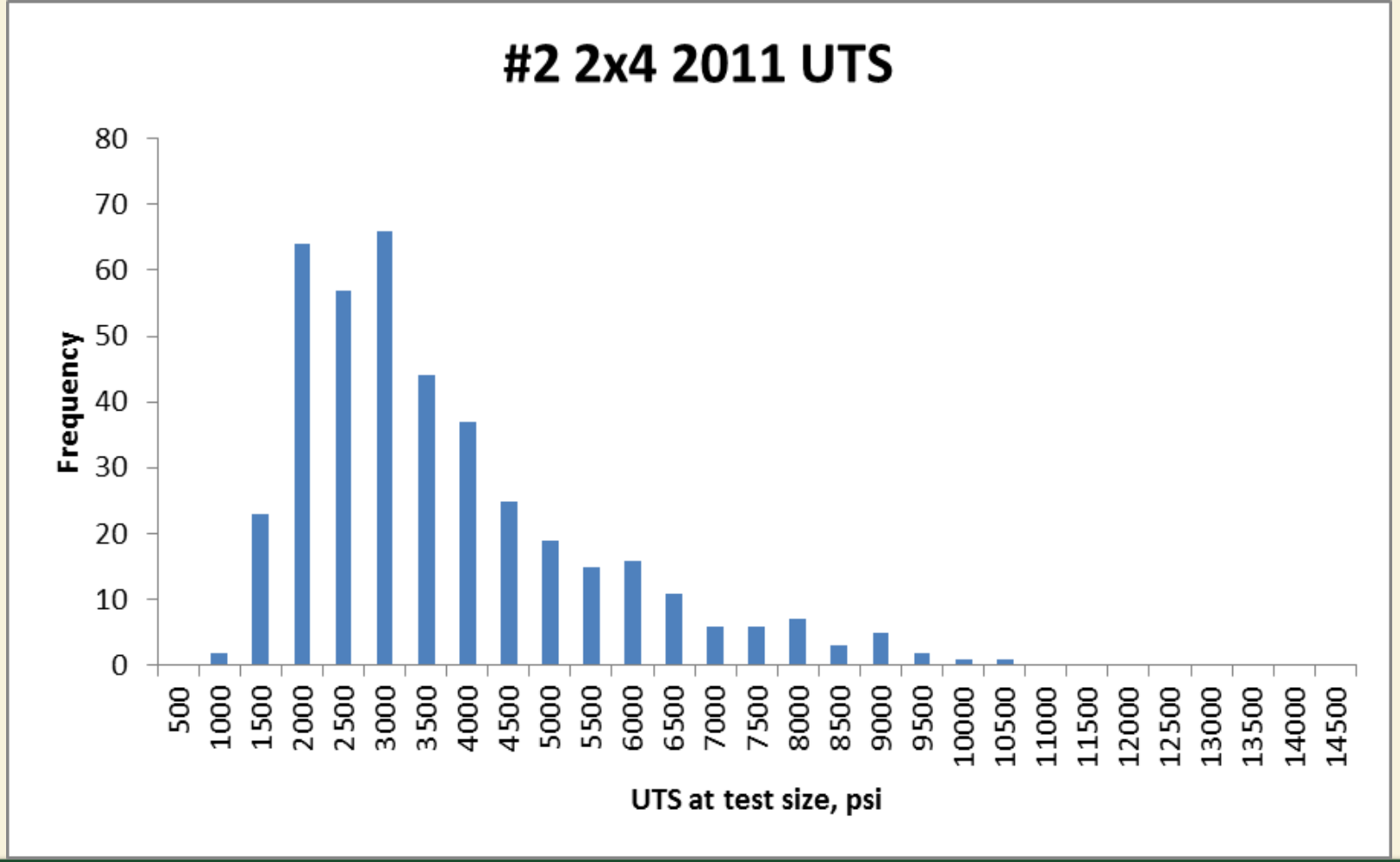
UTS	OIGT	2011
n	405	410
Rank Sum	182,333	150,187
Avg Rank	450	366
Z = -5.09, p = 0.00		

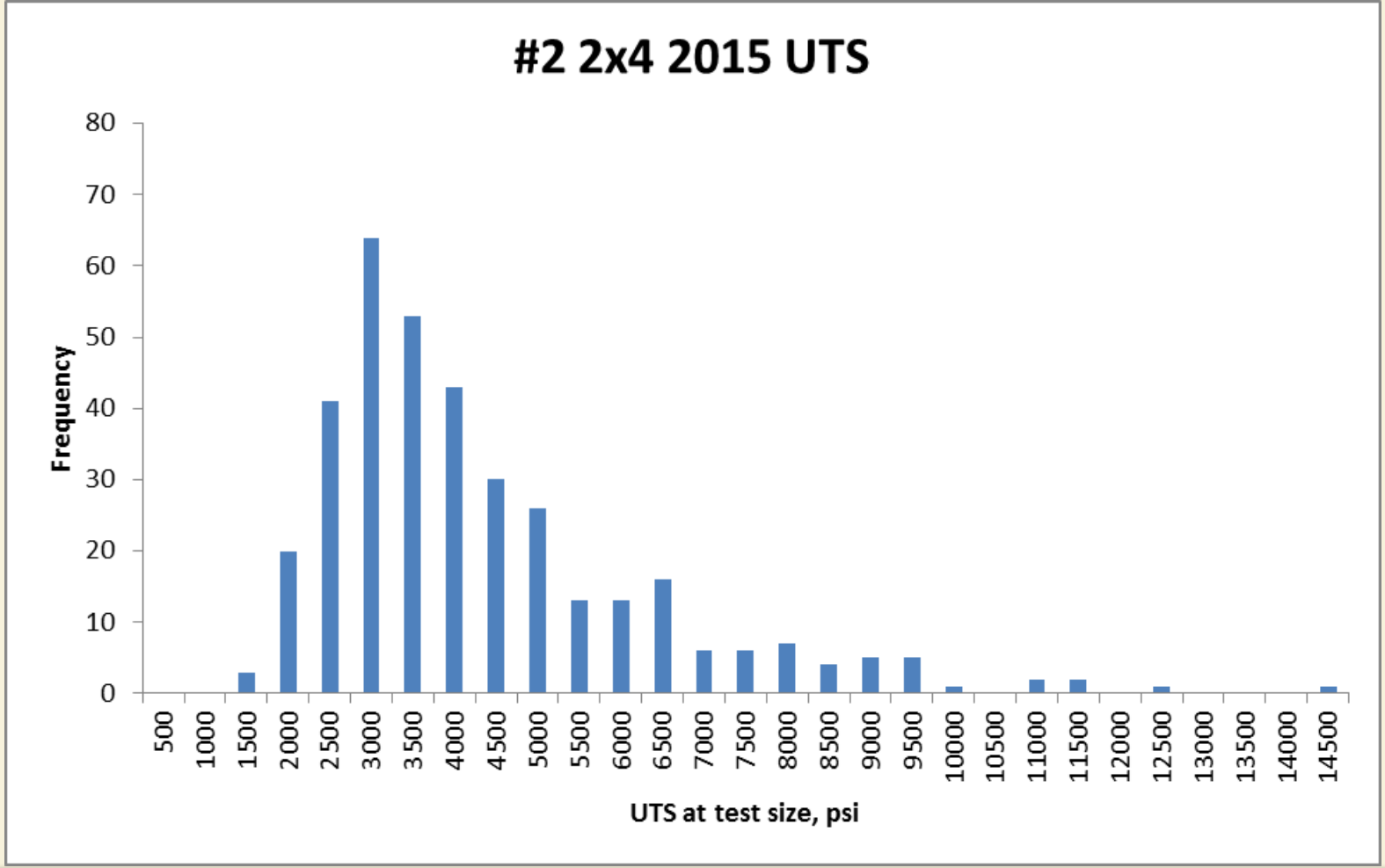
MOE	OIGT	2011
n	413	410
Rank Sum	183,385	155,691
Avg Rank	444	380
Z = -3.88, p = 0.00		

#2 2x4 Original IGT UTS

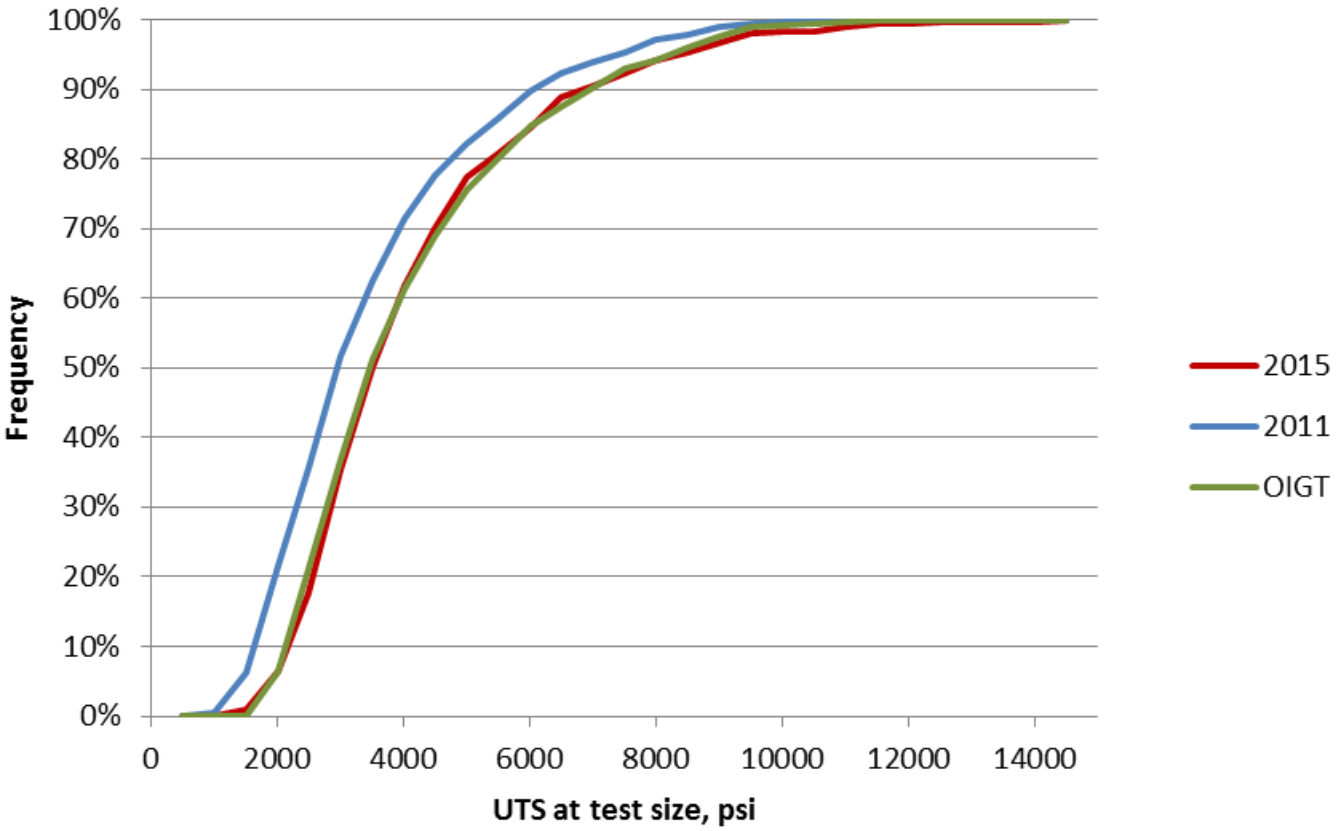
converted to 96"

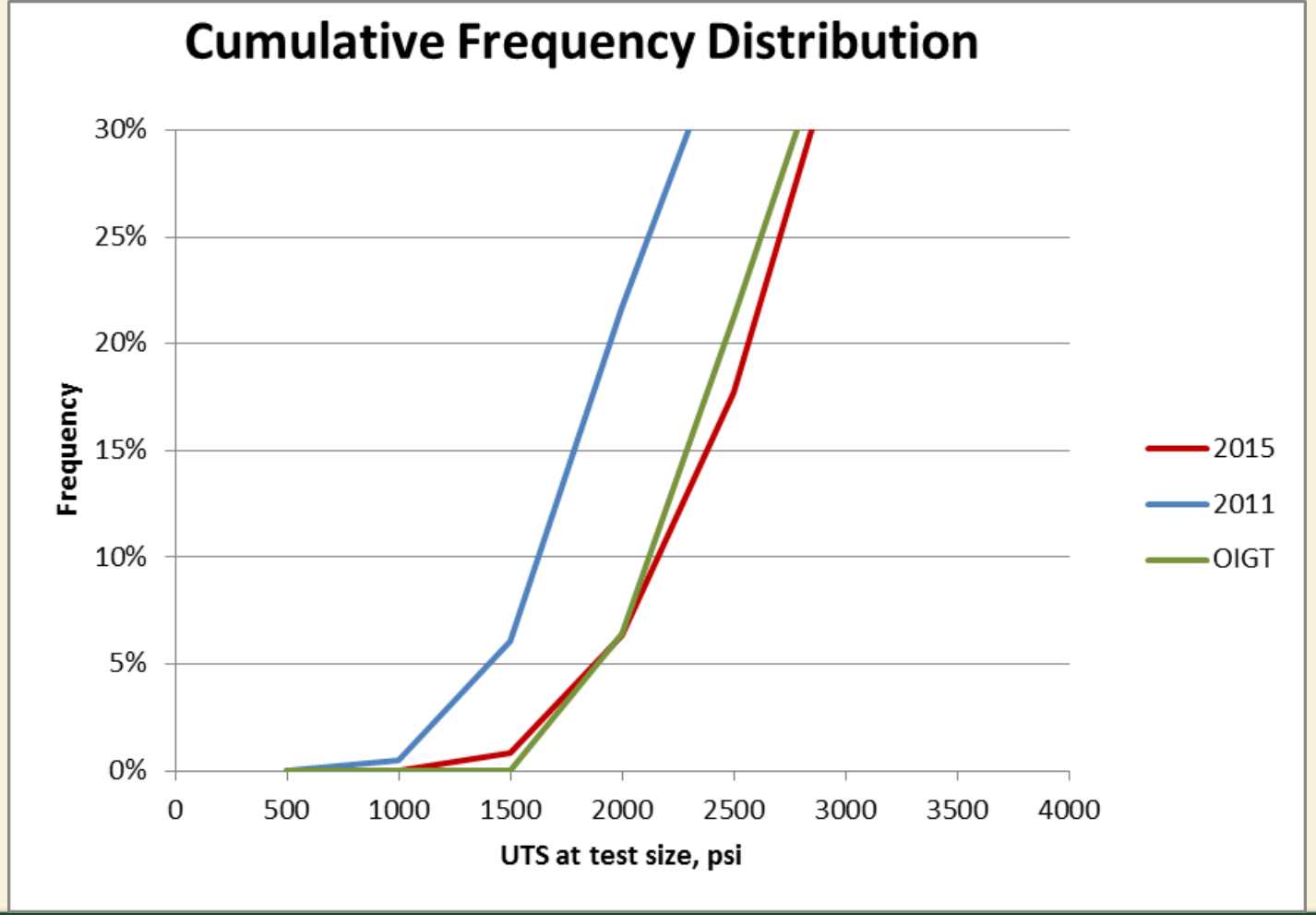



#2 2x4 2011 UTS
Frequency
0
10
20
30
40
50
60
70
80
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500
14000
14500
UTS at test size, psi

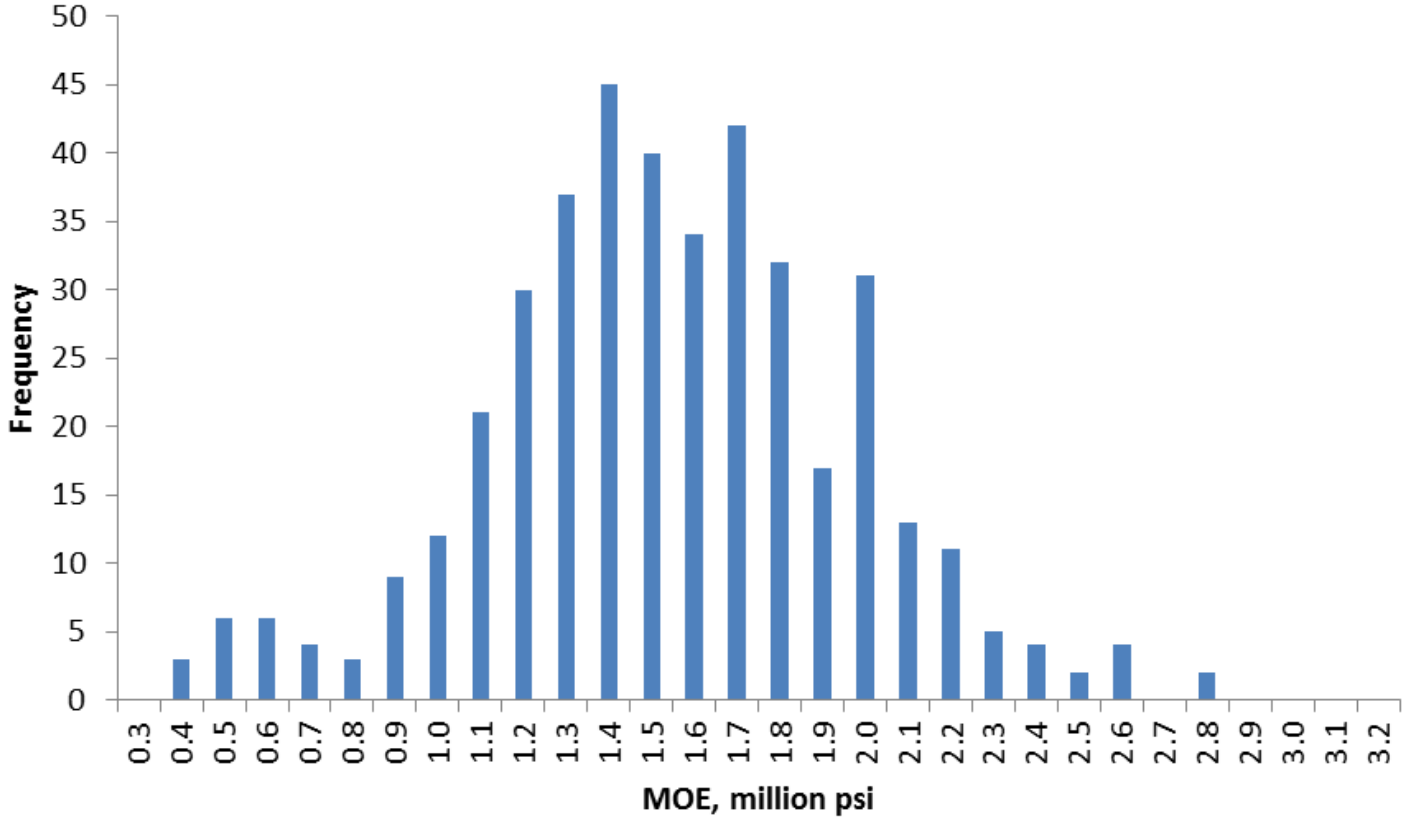

#2 2x4 2015 UTS
Frequency
80
70
60
50
40
30
20
10
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500
14000
14500
UTS at test size, psi

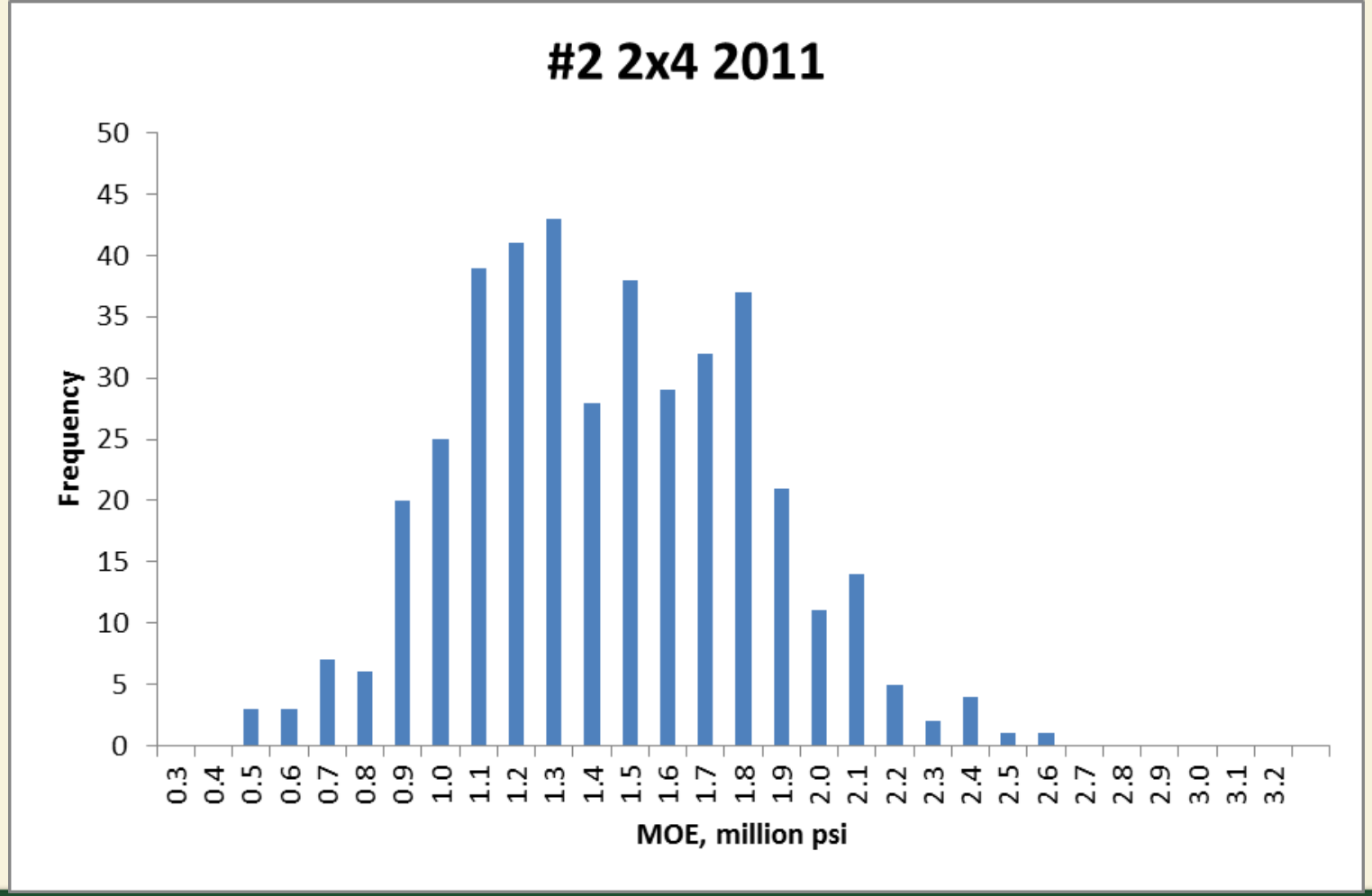
Cumulative Frequency Distribution

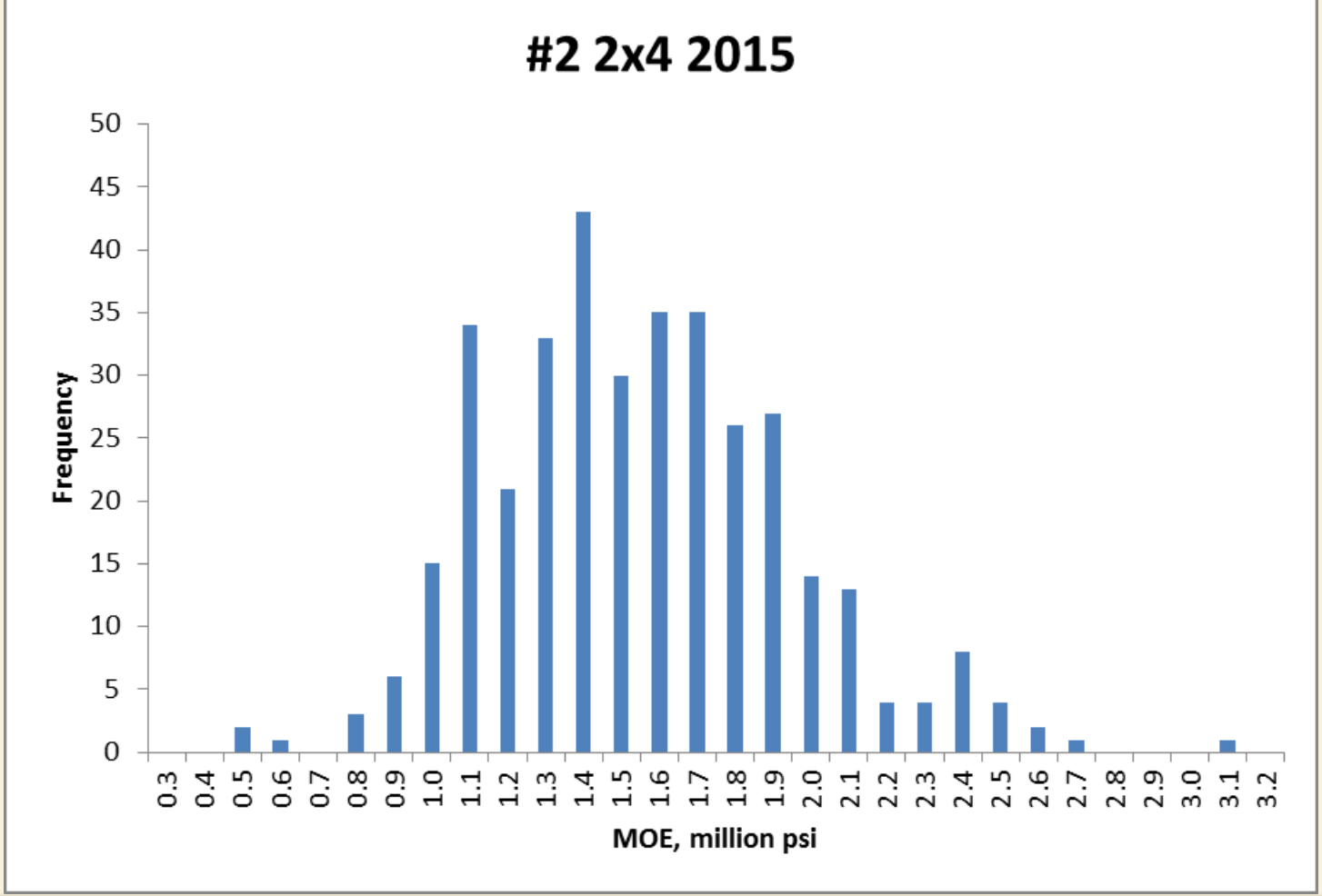


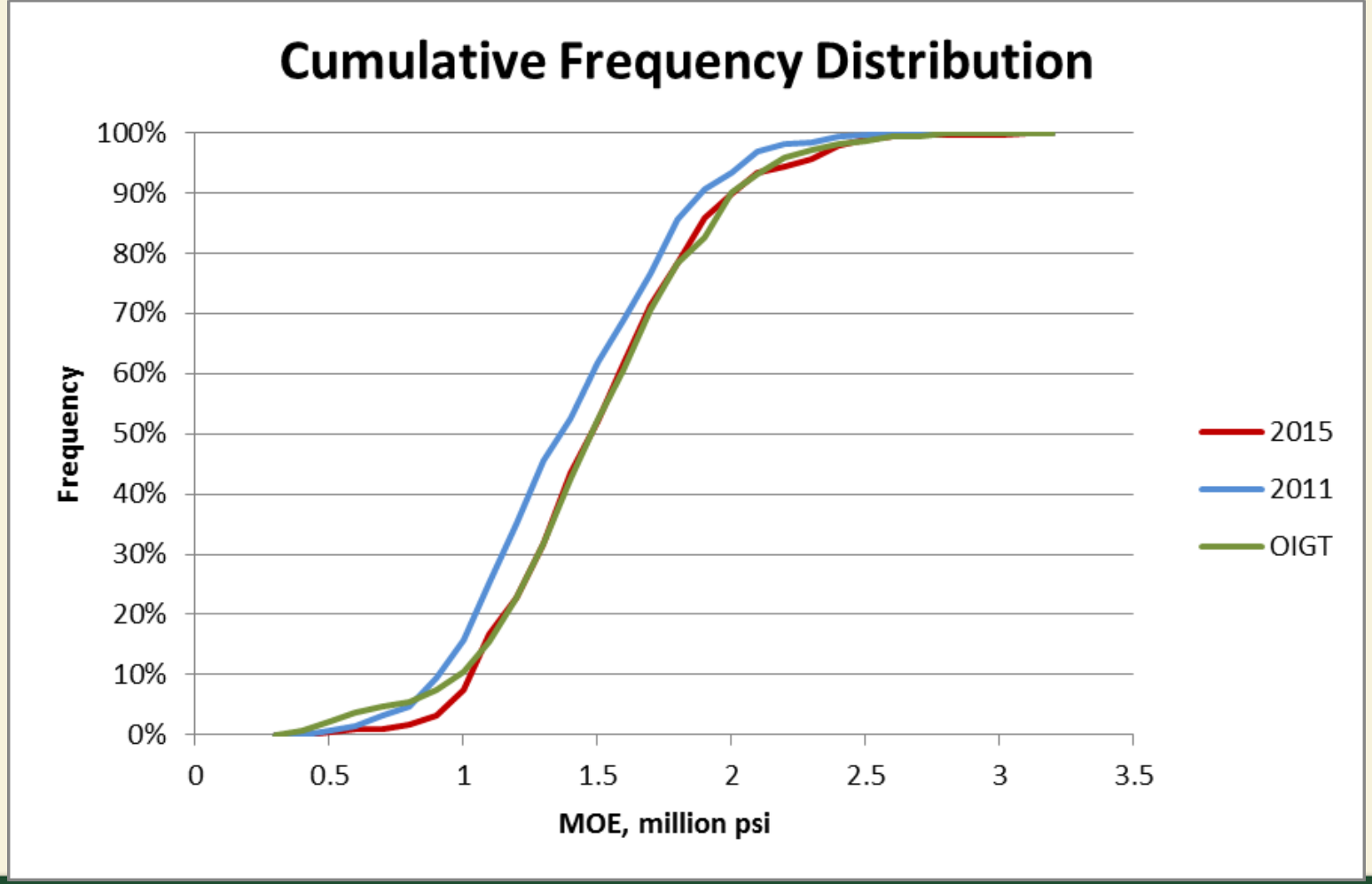

Cumulative Frequency Distribution
30%
25%
20%
15%
10%
5%
0%
Frequency
0
500
1000
1500
2000
2500
3000
3500
4000
UTS at test size, psi
2015
2011
OIGT

#2 2x4 Original IGT




#2 2x4 2011
Frequency
50
45
40
35
30
25
20
15
10
5
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
MOE, million psi


#2 2x4 2015
Frequency
50
45
40
35
30
25
20
15
10
5
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
MOE, million psi


Cumulative Frequency Distribution
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency
0
0.5
1
1.5
2
2.5
3
3.5
MOE, million psi
2015
2011
OIGT

Wilcoxon Results - UTS

	OIGT	2011
n	405	410
Rank Sum	182,333	150,187
Avg Rank	450	366
Z = -5.09, p = 0.00		

	2011	2015
n	410	362
Rank Sum	142,087	156,291
Avg Rank	347	432
Z = -5.30, p = 0.00		

	OIGT	2015
n	405	362
Rank Sum	154,325	140,203
Avg Rank	381	387
Z = -0.39, p = 0.65		

Wilcoxon Conclusions - UTS

- The 2011 sample is significantly different (lower) than the original IGT and the 2015 sample.
- The 2015 sample is not significantly different from the original IGT sample.

Wilcoxon Results - MOE

	OIGT	2011
n	413	410
Rank Sum	183,385	155,691
Avg Rank	444	380
Z = -3.88, p = 0.00		

	2011	2015
n	410	362
Rank Sum	146,311	152,067
Avg Rank	357	420
Z = -3.93, p = 0.00		

	OIGT	2015
n	413	362
Rank Sum	160,230	140,438
Avg Rank	388	388
Z = -0.01, p = 0.50		

Wilcoxon Conclusions - MOE

- The 2011 sample is significantly different (lower) than the original IGT and the 2015 sample.
- The 2015 sample is not significantly different from the original IGT sample.
- A test looking at the entire distribution may be more appropriate for MOE (average value published) than for strength properties (5^{th} percentile basis for design values)

Observations

- 2015 sample is different from 2011, but not in a downward direction
- Moisture content of samples varied
  - Data adjusted for MC
  - 2011 sample much drier
- Presence of combination knots at failure varied
- Percentage of Dense varied

Comparing Samples

	OIGT		2011		2014	2015
	Bending	Tension	Bending	Tension	Bending	Tension
MOR, TL psi	3621		2547		3265	
UTS, TL psi		1867*		1445		1843
Avg E	1.56	1.51	1.35	1.39	1.50	1.51
Avg MC	14.2%	14.0%	11.1%	11.7%	14.7%	14.8%
% Dense	55%	42%	39%	40%	59%	50%
% Comb. Kt	0%	0%	22%	31%	5%	12%

* Adjusted to 8′ gauge length

Observations

- Samples from 2011 have some fundamental differences compared to the original IGT sample and recent (2014-15) 2x4 samples.
- Much drier, many more combination knots

Observations

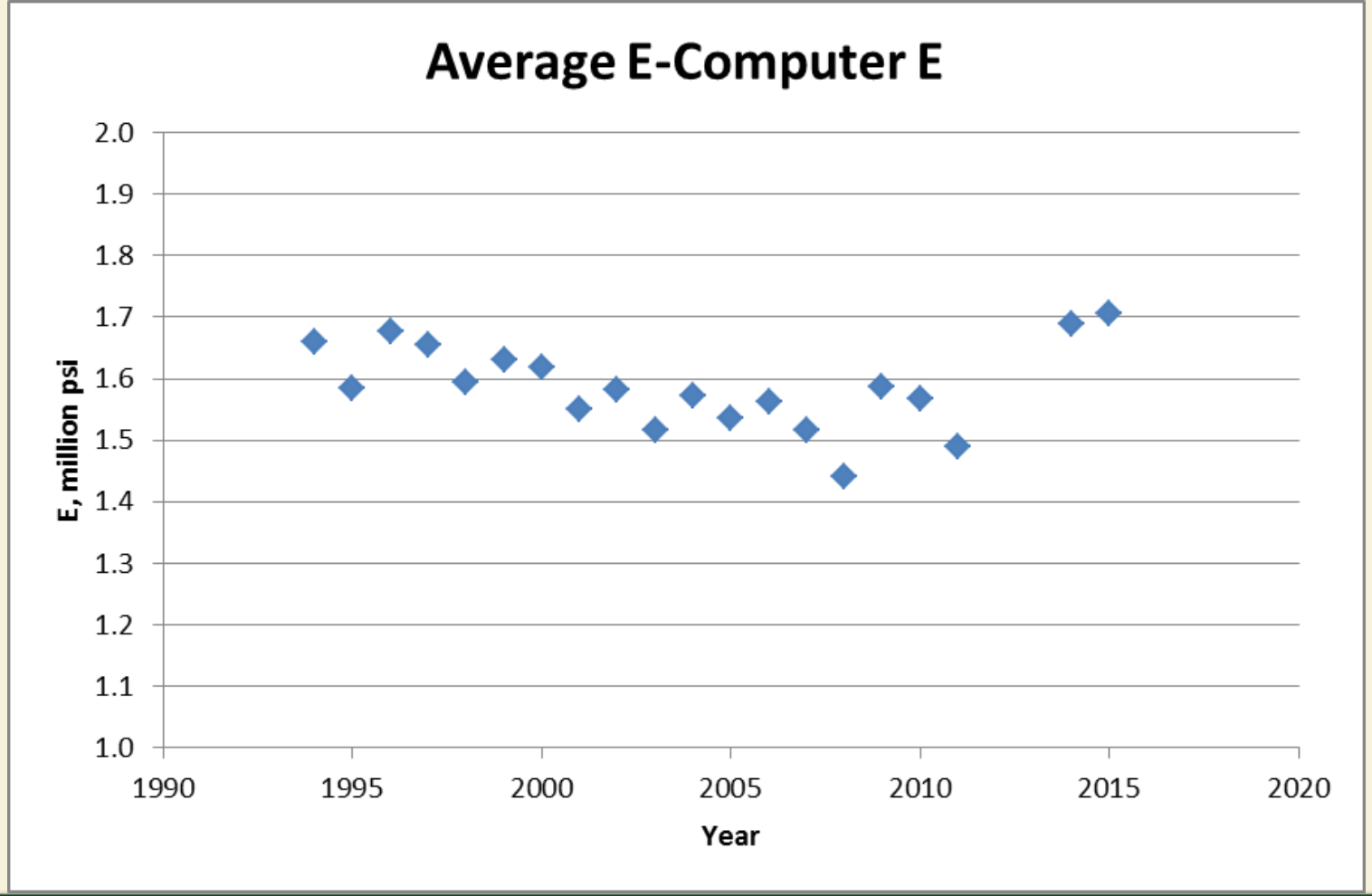
- More variability between samples than expected.
- Appears that present design values represent lower end of what could be included in the grade.

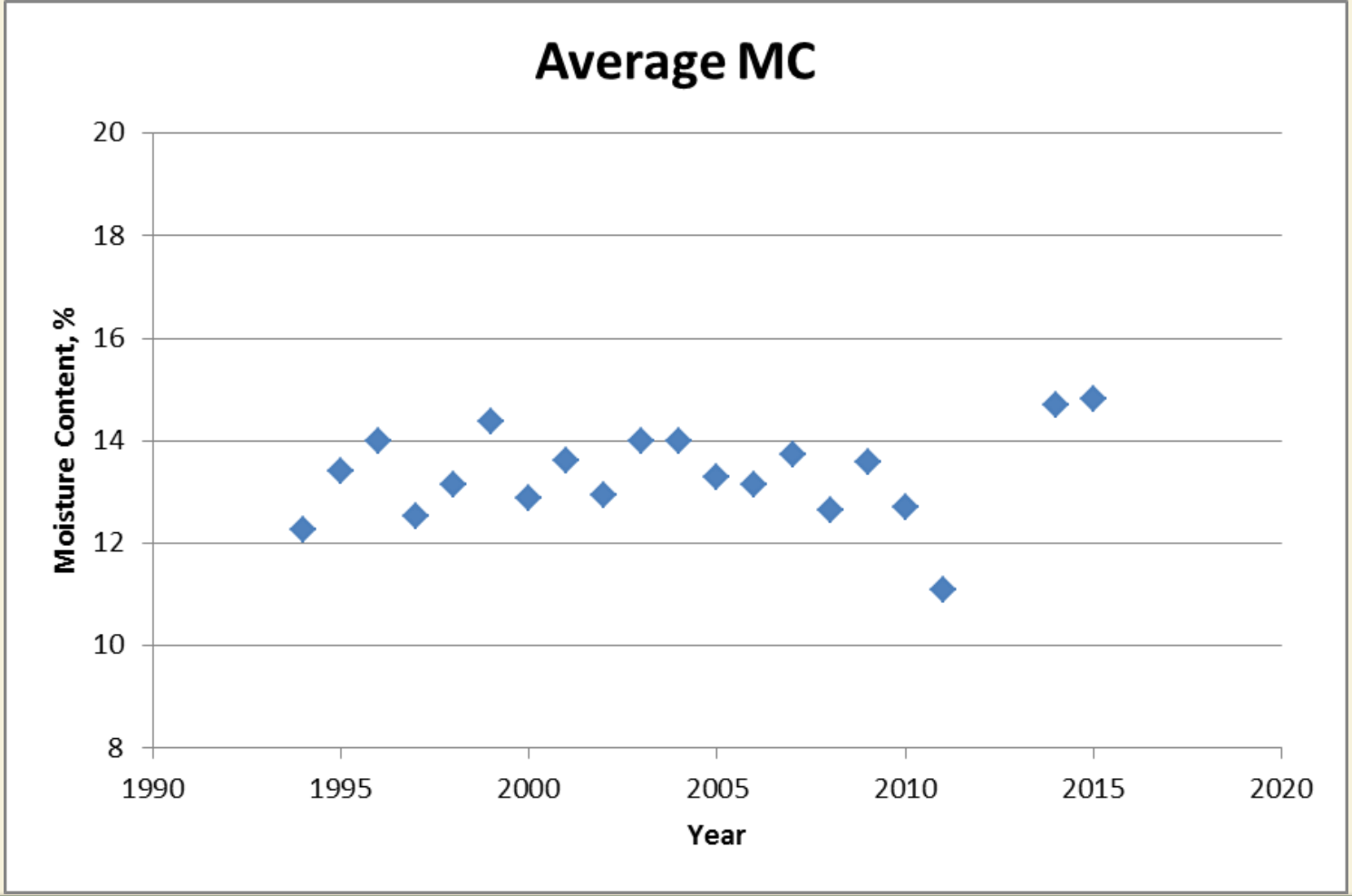
Historical RMP Data

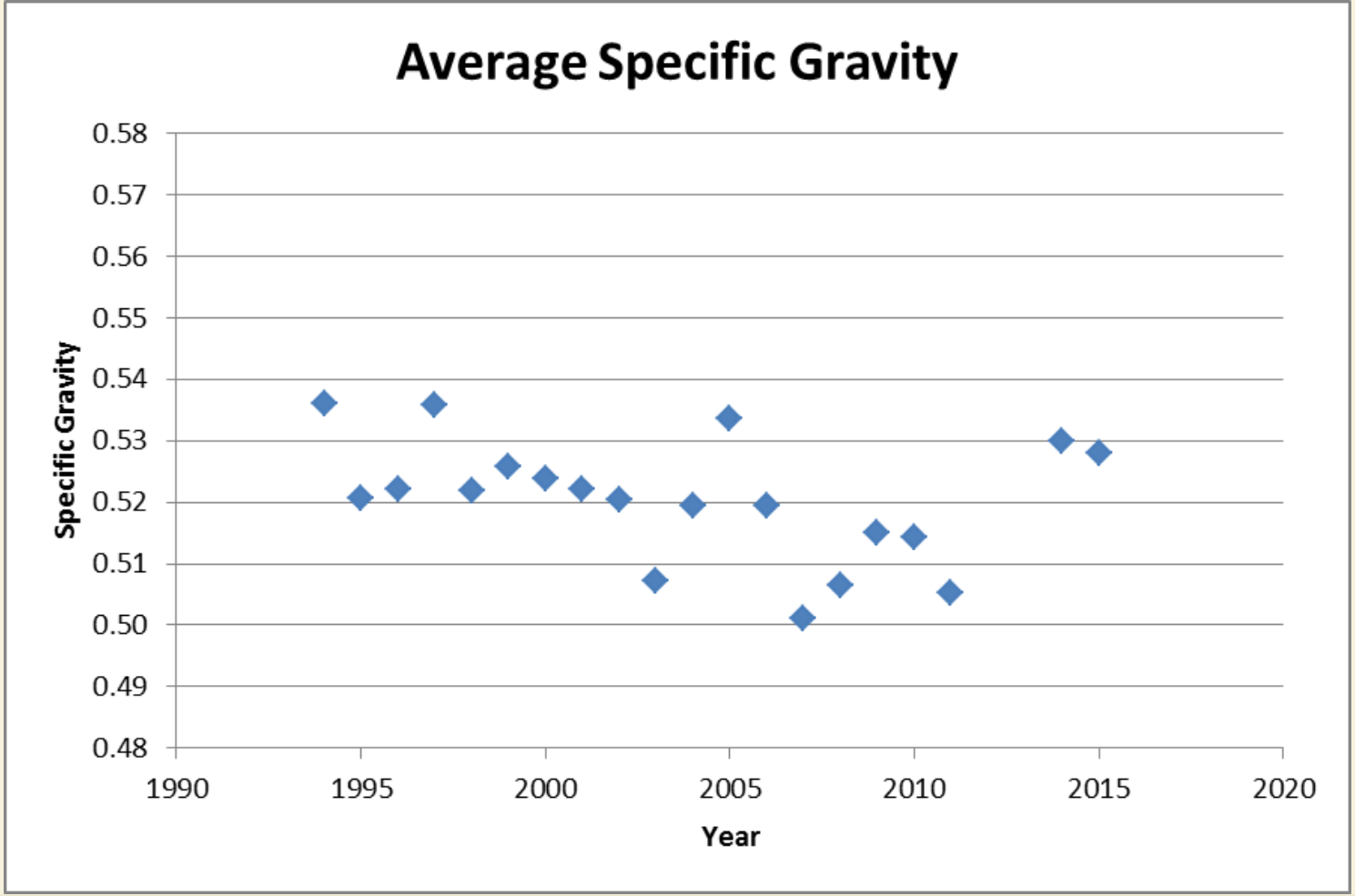
- Since 1994, a non-destructive monitoring program had been conducted by SPIB
- From 1994-2010, a portable E-Computer was used at mill sites to collect data
- Recently identified that flatwise, transverse vibration E is not as correlated to third-point Edge E as we would like

Historical RMP Data

- #2 2x4
- Data was useful to detect trends over time
- Continue collecting E-Computer data in recent/future monitoring samples


Average E-Computer E
E, million psi
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
1990
1995
2000
2005
2010
2015
2020
Year


Average MC
Moisture Content, %
20
18
16
14
12
10
8
1990
1995
2000
2005
2010
2015
2020
Year


Average Specific Gravity
Specific Gravity
0.58
0.57
0.56
0.55
0.54
0.53
0.52
0.51
0.50
0.49
0.48
1990
1995
2000
2005
2010
2015
2020
Year

Future Testing

- Monitoring procedures added to ASTM D1990
- Requirement: Test most commonly produced size/grade every 5 years
- SPIB: Test #2 2x4 every year, alternating between bending and tension
- Test additional wider width every 3rd year

Year	Size	Grade	Property
2011	2x4	#2	E, MOR, UTS
2012	2x4, 2x8, 2x10	SS, #2	E, MOR, UTS, UCS
2013	2x6	#1	E, MOR
2014	2x4	#2	E, MOR
2015	2x4	#2	E, UTS
2016	2x4,2x8	#2	E, MOR
2017	2x4	#2	E, UTS
2018	2x4, 2x8	#2	E, MOR
2019	2x4	#2	E, UTS
2020	2x4, 2x8	#2	E, MOR

Thank You