Composite Structure Engineering Safety Awareness Course

Definition of A- and B-basis Values and An In-depth Look at CMH-17 Statistical Analysis Techniques

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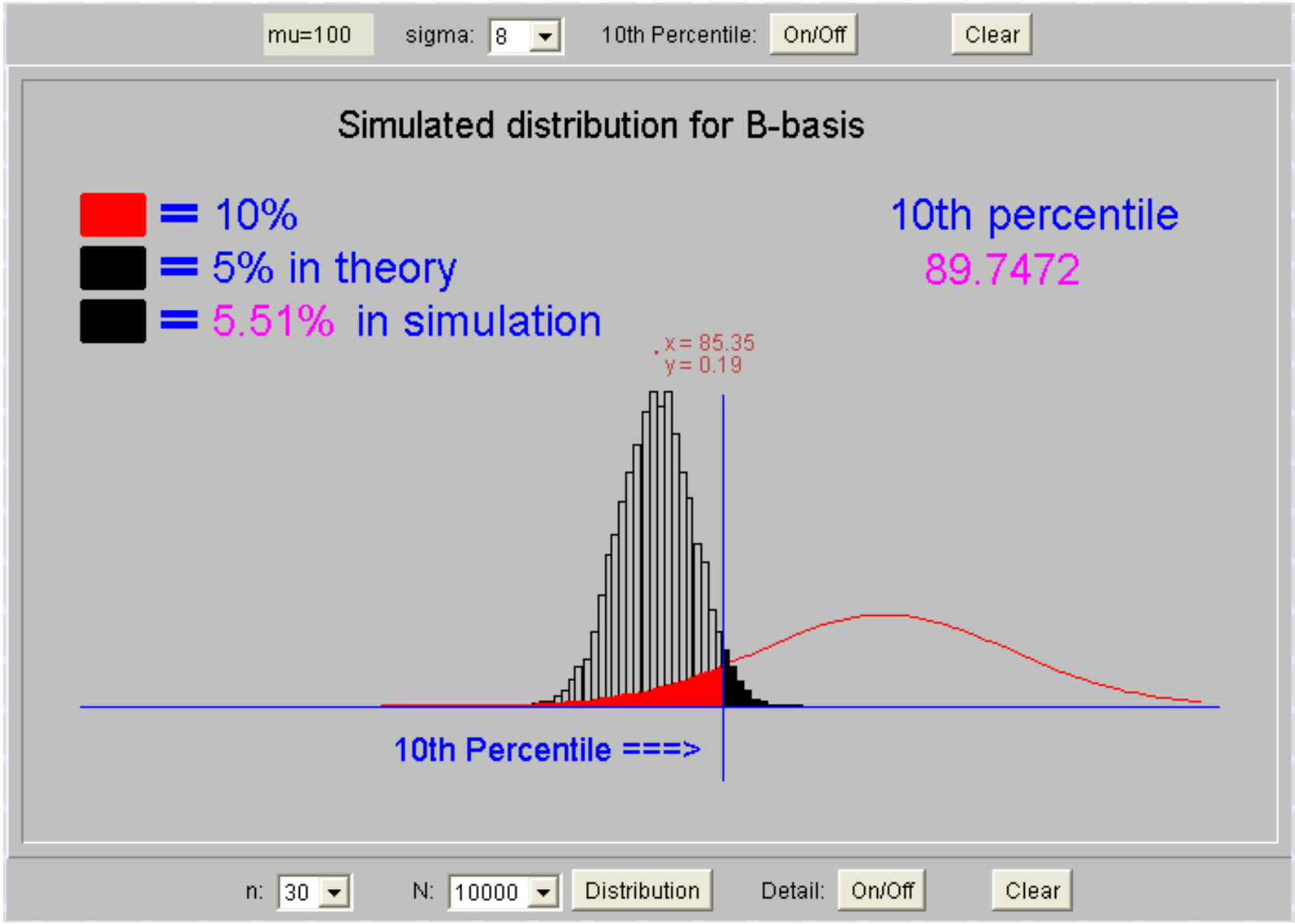
A-Basis and B-Basis Definitions

- Design values must be chosen to minimize the probability of structural failure due to material variability. Compliance is typically shown by selecting design values that ensure material strength with the following probability:
  - Where applied loads are eventually distributed through a single member within an assembly, the failure of which would result in loss of structural integrity of the component; ***99 percent probability with 95 percent confidence interval (that is, A-basis value)***.
  - For redundant structure, in which the failure of individual elements would result in applied loads being safely distributed to other load carrying members; ***90 percent probability with 95 percent confidence interval (that is, B-basis values)***.

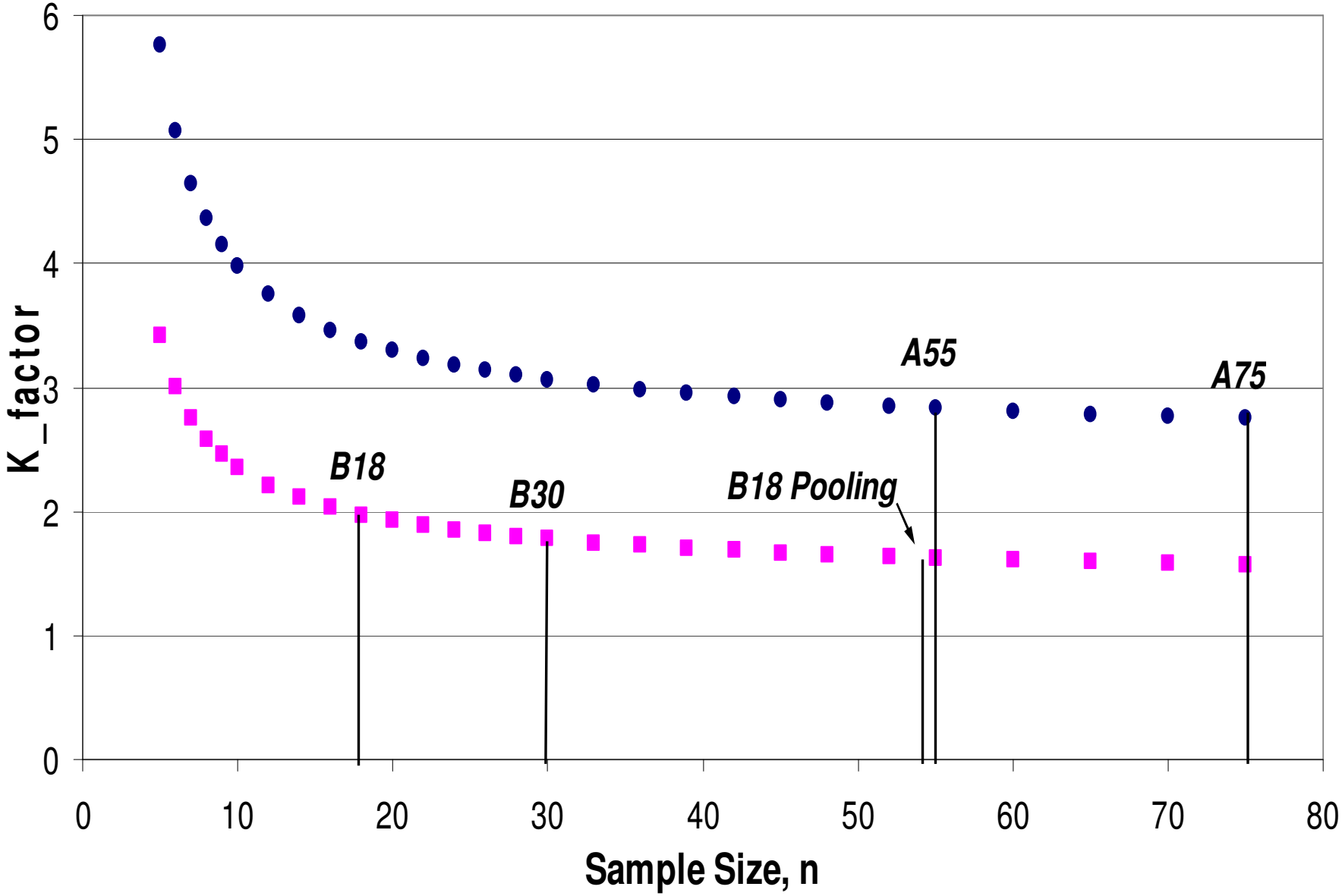
$$A - Basis\ value = \bar{x} - (K_A) \cdot s$$

$$B - Basis\ value = \bar{x} - (K_B) \cdot s$$

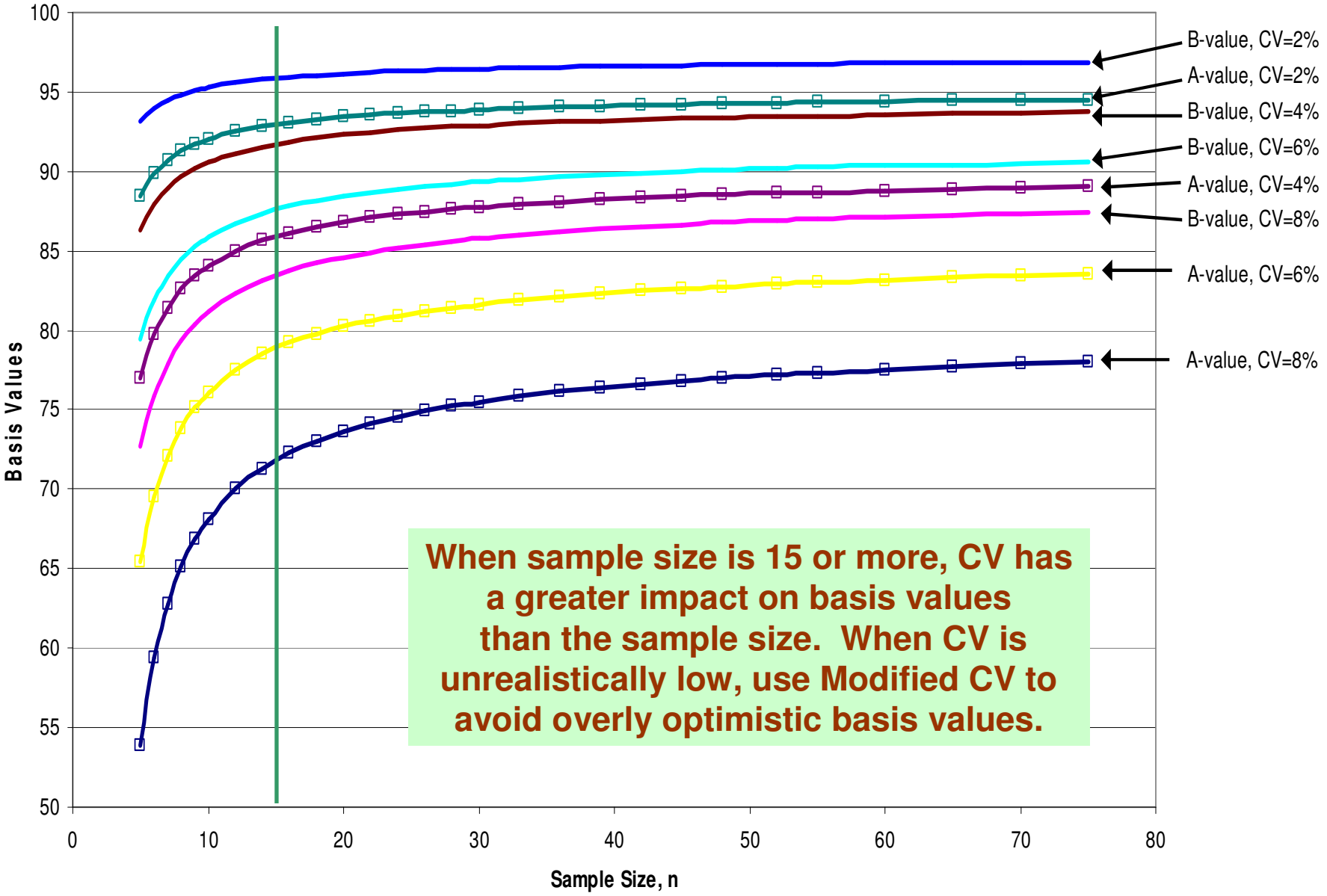


The internet browser-based simulation program is available at NCAMP website
http://www.niar.wichita.edu/coe/ncamp_media.asp

Effect of Sample Size on K_factors



Effects of CV and Sample Size on Basis Values
Mean=100



Methods to Calculate Basis Values

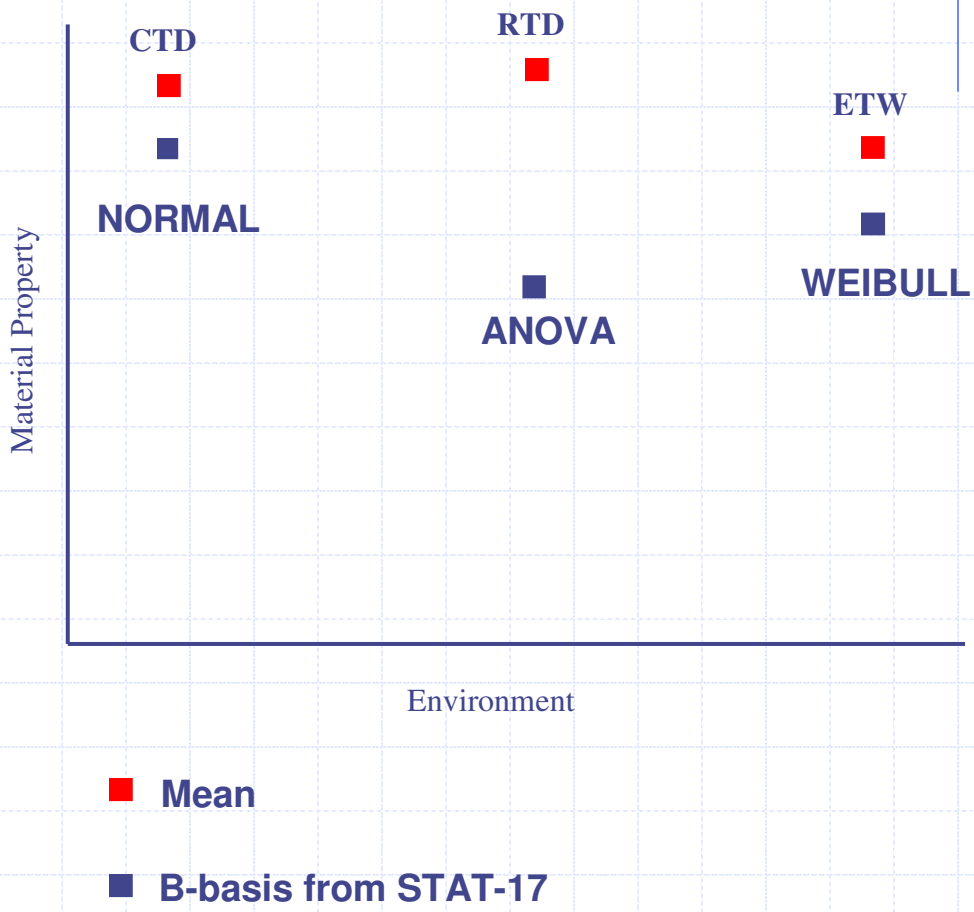
- MIL-HDBK-17F
  - Normal, Weibull, Lognormal distributions
    - Based on Observed Significance Level (OSL)
  - Non-Parametric
  - Batches pooled within environment
  - Data NOT pooled across environments
    - Large sample size required at each environment
  - ANOVA (assumes normal distribution)
  - STAT-17 (a.k.a. Single Point) Excel Spreadsheet Macro (J.Adelmann, Sikorsky Aircraft)
- AGATE (Ref. P.Shyprykevich, ASTM STP 1003, 1989.)
  - Normal Distribution only
  - Batches pooled within environment
  - Data pooled across environments
    - Allowables based on mean of small sample and variability of large pooled sample
  - Published in DOT/FAA/AR-03/19
  - ASAP Excel Spreadsheet Macro (K. Suresh Raju, Wichita State University)
- RECIPE (Ref. M.G.Vangel, A User's Guide to Recipe, NIST, 1994)
  - Normal Distribution only
  - Regression model
  - FORTRAN program

CMH-17 combines the two, giving preference to the AGATE method unless certain assumption are not met

STATISTICAL FACT: Much larger sample size needed to estimate std deviation than to estimate mean

Material Allowable Generation with STAT-17

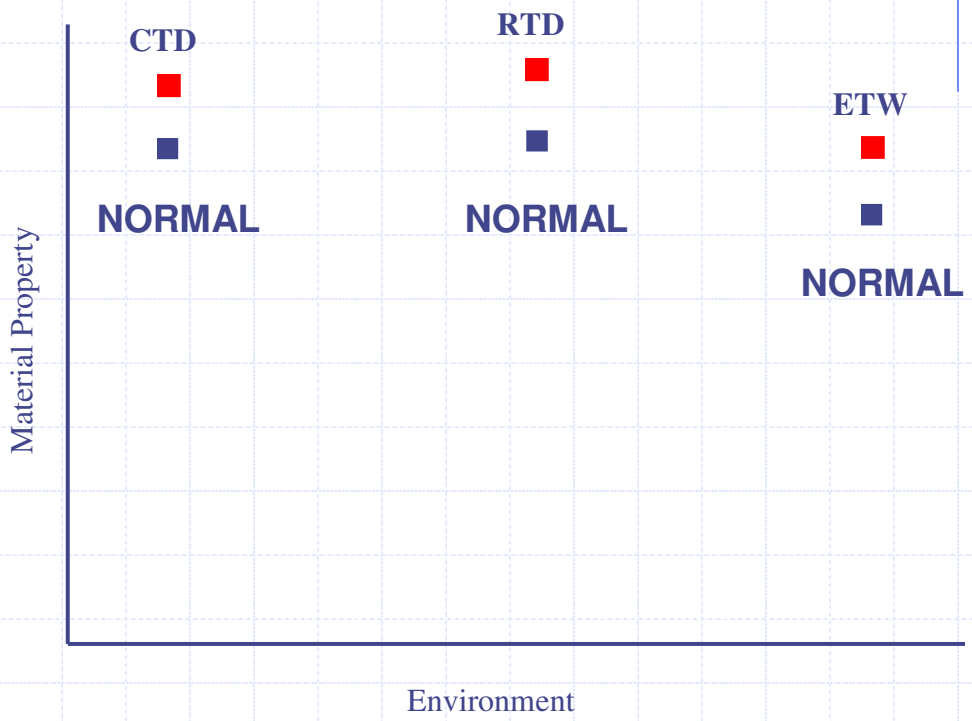
- STAT-17 computes basis values one environment at a time (thus a.k.a Single Point)
- STAT-17 method might result in “distributional changes” which produces allowables that do not make engineering sense
- Extremely difficult to obtain “realistic” load enhancement factors and environmental compensation factor



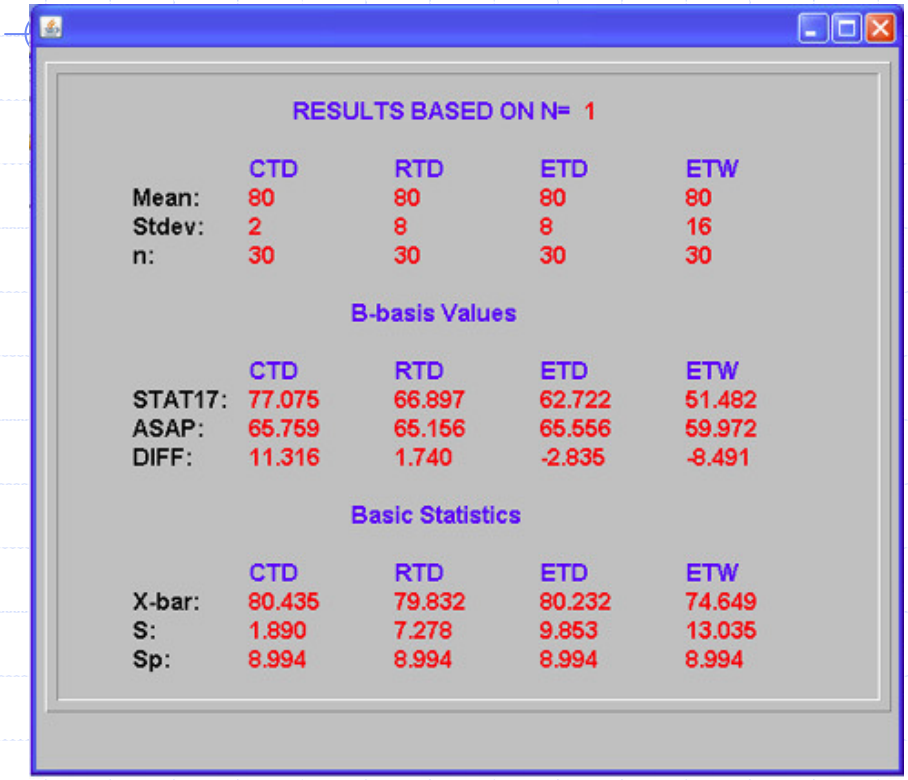
Material Allowable Generation with ASAP

- For the ASAP procedure, only normal distribution is utilized thus eliminating the possibility of "distributional changes"**
- Common (pooled) standard deviation results in equal amount of knock-down for every environment**
- Basis values and mean values follow the same trend

** Must meet requirements of normality and pooling across environment. Otherwise, use STAT-17



Unequal Population Standard Deviations



RESULTS BASED ON N= 1

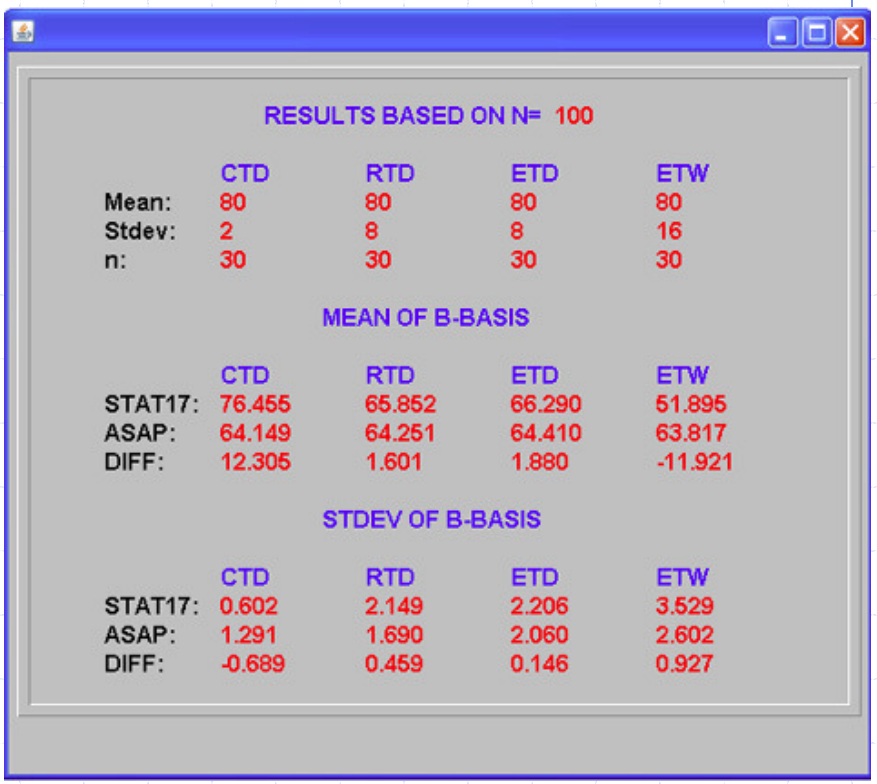
	CTD	RTD	ETD	ETW
Mean:	80	80	80	80
Stdev:	2	8	8	16
n:	30	30	30	30

B-basis Values

	CTD	RTD	ETD	ETW
STAT17:	77.075	66.897	62.722	51.482
ASAP:	65.759	65.156	65.556	59.972
DIFF:	11.316	1.740	-2.835	-8.491

Basic Statistics

	CTD	RTD	ETD	ETW
X-bar:	80.435	79.832	80.232	74.649
S:	1.890	7.278	9.853	13.035
Sp:	8.994	8.994	8.994	8.994



RESULTS BASED ON N= 100

	CTD	RTD	ETD	ETW
Mean:	80	80	80	80
Stdev:	2	8	8	16
n:	30	30	30	30

MEAN OF B-BASIS

	CTD	RTD	ETD	ETW
STAT17:	76.455	65.852	66.290	51.895
ASAP:	64.149	64.251	64.410	63.817
DIFF:	12.305	1.601	1.880	-11.921

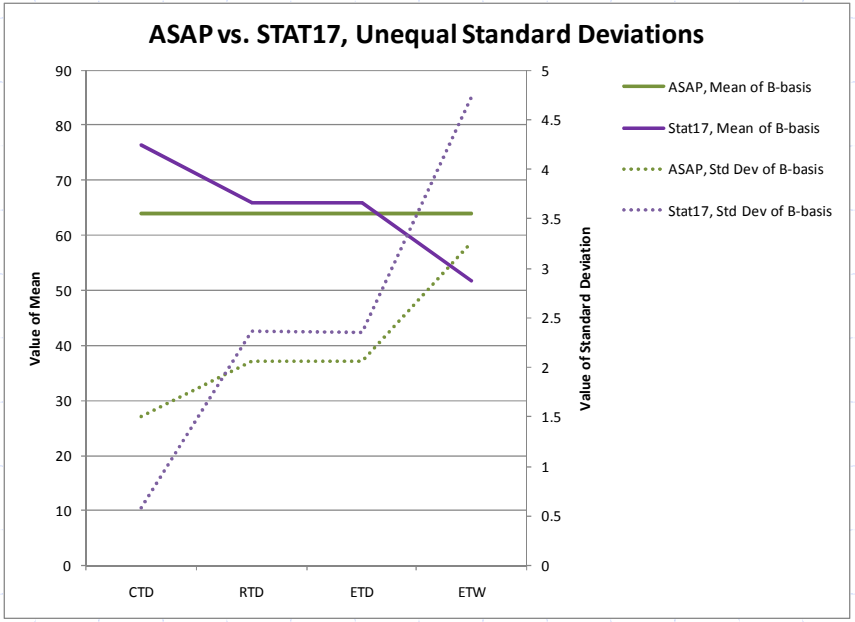
STDEV OF B-BASIS

	CTD	RTD	ETD	ETW
STAT17:	0.602	2.149	2.206	3.529
ASAP:	1.291	1.690	2.060	2.602
DIFF:	-0.689	0.459	0.146	0.927

STAT-17 should be used when population standard deviations are unequal across environment

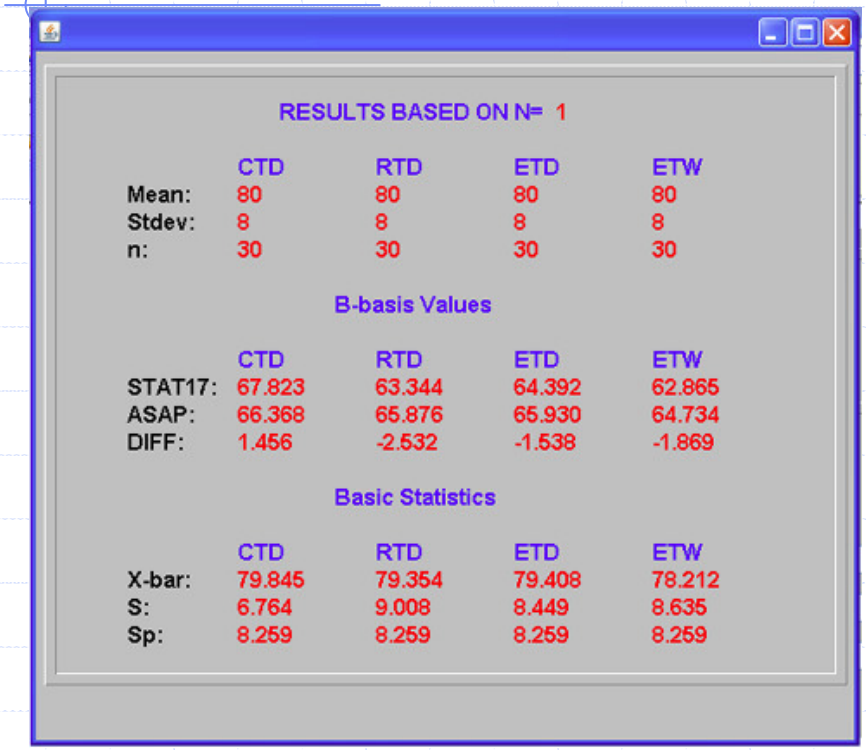
Unequal Population Standard Deviations

- For samples that have significantly different variances, STAT-17 should be used.
- Equality of variance test (Levene's test) is a diagnostic test within ASAP.



	CTD	RTD	ETD	ETW
Mean	80	80	80	80
Stdev	2	8	8	16
n	30	30	30	30

Equal Population Standard Deviations



RESULTS BASED ON N= 1

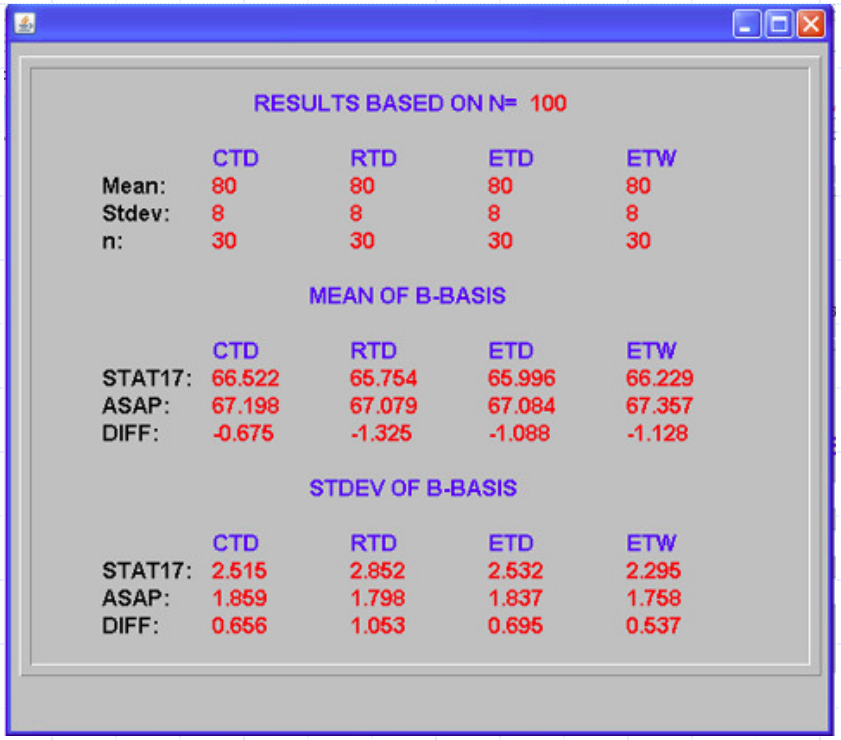
	CTD	RTD	ETD	ETW
Mean:	80	80	80	80
Stdev:	8	8	8	8
n:	30	30	30	30

B-basis Values

	CTD	RTD	ETD	ETW
STAT17:	67.823	63.344	64.392	62.865
ASAP:	66.368	65.876	65.930	64.734
DIFF:	1.456	-2.532	-1.538	-1.869

Basic Statistics

	CTD	RTD	ETD	ETW
X-bar:	79.845	79.354	79.408	78.212
S:	6.764	9.008	8.449	8.635
Sp:	8.259	8.259	8.259	8.259



RESULTS BASED ON N= 100

	CTD	RTD	ETD	ETW
Mean:	80	80	80	80
Stdev:	8	8	8	8
n:	30	30	30	30

MEAN OF B-BASIS

	CTD	RTD	ETD	ETW
STAT17:	66.522	65.754	65.996	66.229
ASAP:	67.198	67.079	67.084	67.357
DIFF:	-0.675	-1.325	-1.088	-1.128

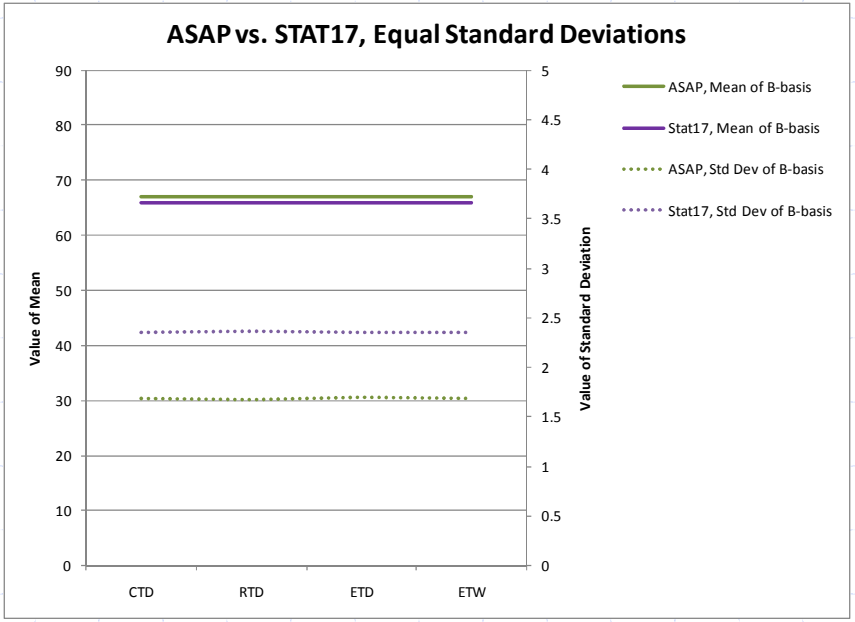
STDEV OF B-BASIS

	CTD	RTD	ETD	ETW
STAT17:	2.515	2.852	2.532	2.295
ASAP:	1.859	1.798	1.837	1.758
DIFF:	0.656	1.053	0.695	0.537

ASAP produces slightly higher and more stable basis values

Equal Population Standard Deviations

- For samples with equal variances, ASAP will provide basis values that are higher than STAT-17 and those basis values will have less fluctuation due to random differences between samples.



	CTD	RTD	ETD	ETW
Mean	80	80	80	80
Stdev	8	8	8	8
n	30	30	30	30

Conclusions

- Standard deviations can be very unstable when sample size is small (<30); resulting in very erratic basis values, unless pooling method is used
- Basis values are not material properties
  - they are not fixed values because they depend on the number of specimens you test (i.e. how big your budget is)
  - If you test more specimens, chances are, you will get a higher basis value
- Basis values will vary each time you repeat the program
  - Don't be surprised if you get a different number each time (because you should get a different number each time)
- Pooling across environment (ASAP) will typically produce higher and more stable basis values; but it has more stipulations
- Single point (STAT-17) is more flexible because it can handle datasets with batch-to-batch variability, unequal variances across environment, and various distributions; but it sometimes may produce basis values that seem illogical to engineers
- Therefore, CMH-17 gives preference to ASAP. STAT-17 is used when ASAP cannot be used.