VDOT END RESULT SPECIFICATION (ERS)

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Goal

- To have consistent quality concrete provided to VDOT
- Pay based on the quality of concrete

Differences in Specifications

Item	Current	ERS
Mix Design	Prescriptive	Performance Measures
Testing	VDOT	Contractor and VDOT
Basis of Pay	Minimum	PWL

ERS

Includes

- QC Plan by the Contractor
  - Applicable to preconstruction and during construction
- Mix design approval
- Acceptance

Sampling and Testing (Acceptance)

- After 2 ft^3 is discharged
- Screening tests: every load by the Contractor (air content, slump, unit weight, temperature)
- Pay factor tests: randomly one per sublot by VDOT (strength and permeability, PWL)

Statistics is a tool used in QA

Statistics is the science that deals with the treatment and analysis of numerical data

Variability

- **Variability** – everything varies
- **Variability** can be controlled, but cannot be eliminated. Each material and process has some inherent variability
- Assignable variability can be reduced **IF** we identify the cause

QC/QA and Variability

variability + variability + variability + Variability

(sampling) (test method) (materials) (construction)

$$S^2 = S^2_s + S^2_t + S^2_m + S^2_c$$

= Variability

Ideal World

$$S^2 = \cancel{S^2_s}^{0} + \cancel{S^2_t}^{0} + S^2_m + S^2_c$$

$$S^2 = S^2_m + S^2_c$$

In Real World try to minimize $S^2_s + S^2_t$

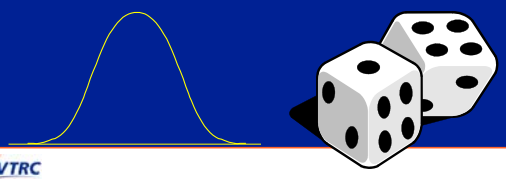
Material and construction variability

- **Material variability** is due to the random variation that naturally exists in a given material.
- **Construction variability** is the result of variation that is inherent in the production and construction methods.
- In the ERS, currently the Material Variability is measured and the Construction variability is being studied.

Nature avoids absolutes – variation is the rule.

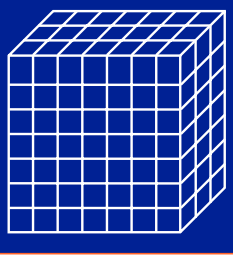
Scientific Tools to Use in the Treatment and Analysis of Variability

- **Statistics**
- **Random sampling**

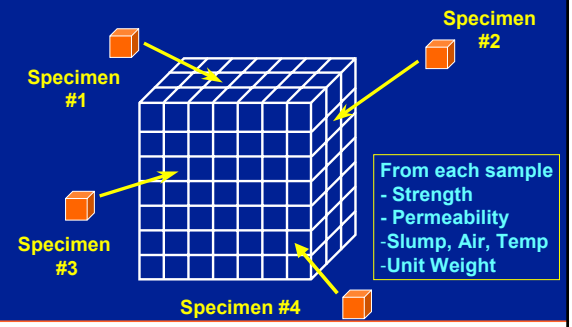


Population (A set of units)

147 units or elements



Sample from the Population or Lot (A subset of the units of a population)



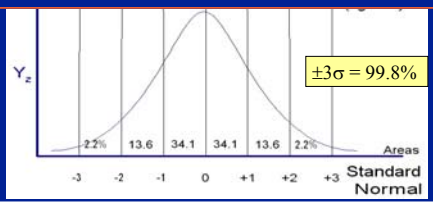
Normal Distribution

Basically, the…

$$y = \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-(x-\bar{x})^2/2\sigma^2}$$

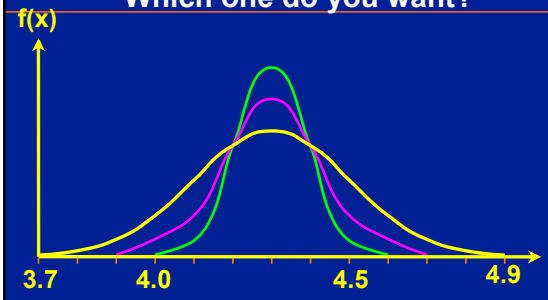
…is a bell-shaped curve.

Approximate Areas

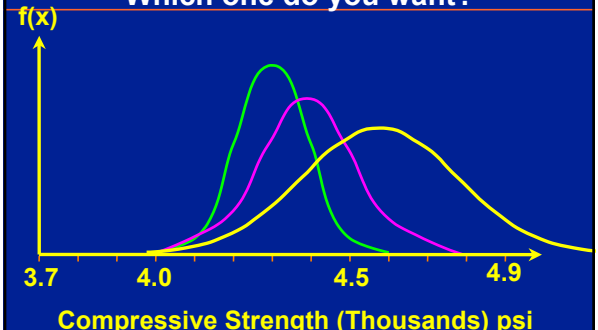


Mean ± 1 Standard Dev	68.2% of Area
Mean ± 2 Standard Dev	95.4% of Area
Mean ± 3 Standard Dev	99.8% of Area

Same Mean – Different Distribution, Which one do you want?



Different Mean – Different Distribution, Which one do you want?



Estimating PWL

- Compressive strength
  Q_L = (Average – LSL)/s
- Permeability
  Q_U = (USL – Average)/s

Q is the Quality Index, used to estimate PWL (percent within limits) from Tables
LSL: lower specification limit
USL: upper specification limit
s: sample standard deviation

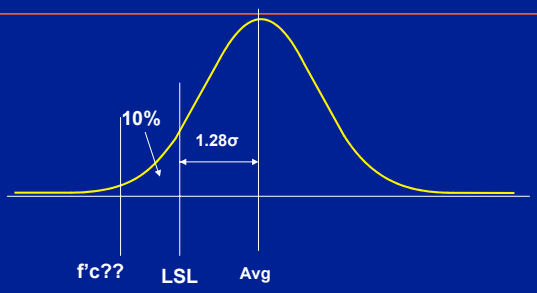
Pay Factor

- PWL for strength and permeability:
  PF = 82 + 0.2 (PWL)
  100% pay for PWL = 90%
- Average pay factor:
  C1(Perm)+C2(Str)/(C1+C2)
  C is a weighting factor
- Total pay factor = Avg pay factor times unit bid price plus the additional price adjustment for deficient thickness (pavement) and incentive or disincentive for the ride quality.

Intent

- In the selection of LSL or USL the intent is to match the average quality of concretes delivered to VDOT over the years
- Relationship between f'_c and LSL sought
- Variability is included to ensure uniform consistent product

Selection of LSL



% below f'c → Avg → LSL → Pay Factor

Example 1

- Average of 3 tests=5000 psi
- Standard Deviation=338 psi
- f'c is 4000 and LSL 4500 for deck
- Q=(5000-4500)/338=1.48
- PWL from Table=100%
- PF = 82+0.2(100)=102

Example 2

- Average of 3 tests=5000 psi
- Standard Deviation=600 psi (higher variability than Example 1)
- f'c is 4000 and LSL 4500 for deck
- Q=(5000-4500)/600=0.83
- PWL from Table=75.53 %
- PF = 82+0.2(75.53)=97.11

Example 3

- Average of 3 tests=5160 psi (higher than Example 2)
- Standard Deviation=600 psi
- f'c is 4000 and LSL 4500 for deck
- Q=(5160-4500)/600=1.10
- PWL from Table=90.16 %
- PF = 82+0.2(90.16)=100.03

First Pilot Projects

Salem:

Route 11 over the New River and Norfolk Southern Railroad tracks near Radford University

Culpeper:

Route 28 near Manassas

Salem Mix Proportions

Material	Amount (lb/yd^3)
Cement Type I/II	318
Fly ash Class F	159
Slag	159
Fine aggregate	1101
Coarse aggregate	1755
w/cm	0.45

Salem Strength and Permeability

	Average (psi)	Std Dev
Strength	5016	305
Permeability	391	72

N=31

Proposed Projects

Each District will incorporate the ERS on two (preferred) of the following projects that will be advertised from 10/06 to 7/07

ERS Projects

DISTRICT	PROJECT	ADVERTISEMENT DATE
Bristol	PM07-084-186,C501	December 12, 2006
Culpeper	To Be determined	
Fredericksburg	Rte. 608 over Rte. 95 Spotsylvania Co.	June 2007
	Rte. 3 over Piankatank River -Mathews	September 2008
	Rte. 624 over Cat Point Creek - Richmond	December 2006
Hampton Roads	Rt. 175 – Chincoteague	August 2006
Lynchburg	Rt. 734 – Bridge over Cane Creek 948	February 13, 2007
Northern Virginia	Rt. 1 Bridge replacement at Neabsco Creek 16422	May 8, 2007
	I-95 – Fourth Lane	November 27, 2006
Richmond	Rt. 5 over Chickahominy	August 2006
Salem	Rt. 723 Bridge over Nininger Creek 71610	February 2, 2008
Staunton	North Oak lane bridge replacement 60982	October 10, 2006
	Rt 340 Bridge at Jeremy's Run 11091	April 10, 2007

Concern

- How to resolve disagreement between the producer and the contractor concerning defects (scaling, cracking, lack of air) in the structure.
- VDOT deals with the Contractor. Producer and contractor must solve issues between each other. ERS will help since it will ensure that the concrete supplied meets the specs!

Concern

- Too many samples!
- Basically we are following the frequency used currently. However, testing more samples minimizes uncertainty.

Concern

- VDOT will not get bids or it will be very high!
- Did not happen.
  - Rte 5: price was not high!
  - Rte 624: had bids.
  - Rte 175: a plant will be set

Concern

- Only those with uniform and consistent product will benefit!
- That is the goal. All producers will be knowledgeable about their material.

Concern

- Penalty!
- Quality control prior to construction will ensure that acceptable product is delivered to the jobsite. Thus, penalty should not be an issue!

Concern

- Small producers will not be able to compete or produce considering the cost of testing.
- Small producers will also benefit from quality control. They will not waste material since they will be in control of their process.

Next Steps

- Projects selected by districts to be used with out pay factor (PWL)
- Monitor pilot projects and collect data
- Resolve issues with stake holders
- Modify the ERS special provisions

Industry Trend

- NRMCA promotes P2P
  - Prequalification
  - Identity testing

Thank You

VTRC
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