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# **Overview of 2008 REU Research Project 1:** **“Study of the Ductility and Deformation of** **High Strength in Tension”**

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# Background...

- Bolts are a common connection component in structural applications
- Bolts are high strength and easier/less time consuming than welding or riveting connections
- Load and Resistance Factor Design (LRFD) allows for only 75% of bolt tension and shear strength in design
- Creates more expensive connections because more bolts are needed
- Factored design strength NOT based on statistical data



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# Goals and Objectives...

- To create well defined resistance factors for the design of connections using high-strength bolts
  - Resistance factors will be calculated based on reliability indices and statistical reduction
  - Overall result will produce connections designs that are more economic and thus more competitive
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# Problem to be Evaluated...

- Load and Resistance Factor Design (LRFD) philosophy is based on reliability indices and resistance factors

$$\phi R_n \geq \sum_{i=1}^n \gamma_i Q_{im}$$

- Currently  $\phi = 0.75$  (AISC 2005) for tensile and shear strength of bolts
- Conservative value is believed to be based on perceived brittle failure modes and not based on a statistical analysis

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# Scope of Testing...

- ❑ Fastener testing according to ASTM
    - Bolts to be tested in:
      - ❑ Direct Tension
      - ❑ Direct Shear
        - Threads excluded from shear plane
        - Threads NOT excluded from shear plane
  - ❑ Reliability analysis of the experimental data
  - ❑ Study ductility of high-strength bolts
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# Tension and Shear Testing

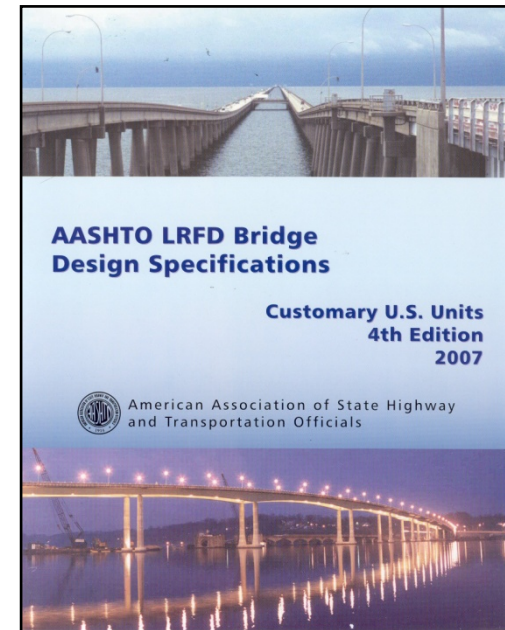


# Philosophy of LRFD Design...

- For Safety:

$$\sum \gamma Q \leq \phi R_n$$

- $Q$  - Load Effect
- $R$  - Component Resistance
- $\gamma$  - Load Factor
- $\phi$  - Resistance Factor



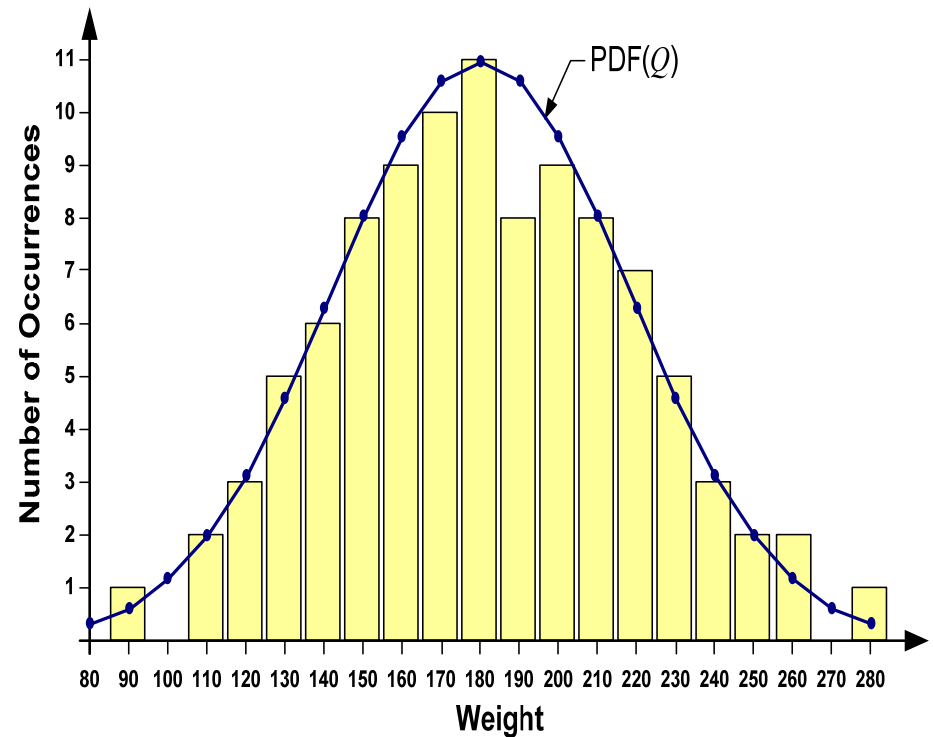
# Variability of Loads:

- Suppose that we measure the weight of 100 students...

Weight	Number of Samples	Weight	Number of Samples
70	0	180	11
80	0	190	8
90	1	200	9
100	0	210	8
110	2	220	7
120	3	230	5
130	5	240	3
140	6	250	2
150	8	260	2
160	9	270	0
170	10	280	1

Average = 180<sup>lbs</sup>

St Deviation = 38<sup>lbs</sup>

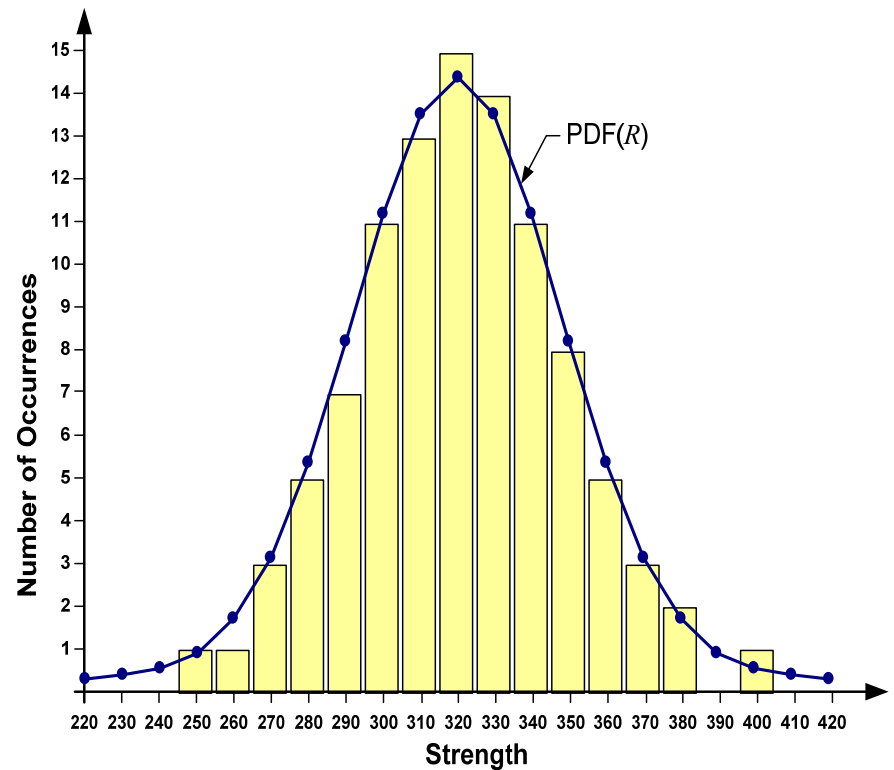


# Variability of Resistances:

- Now suppose that we measure the strength of 100 ropes...

Weight	Number of Samples
210	0
220	0
230	0
240	0
250	1
260	1
270	3
280	5
290	7
300	11
310	13

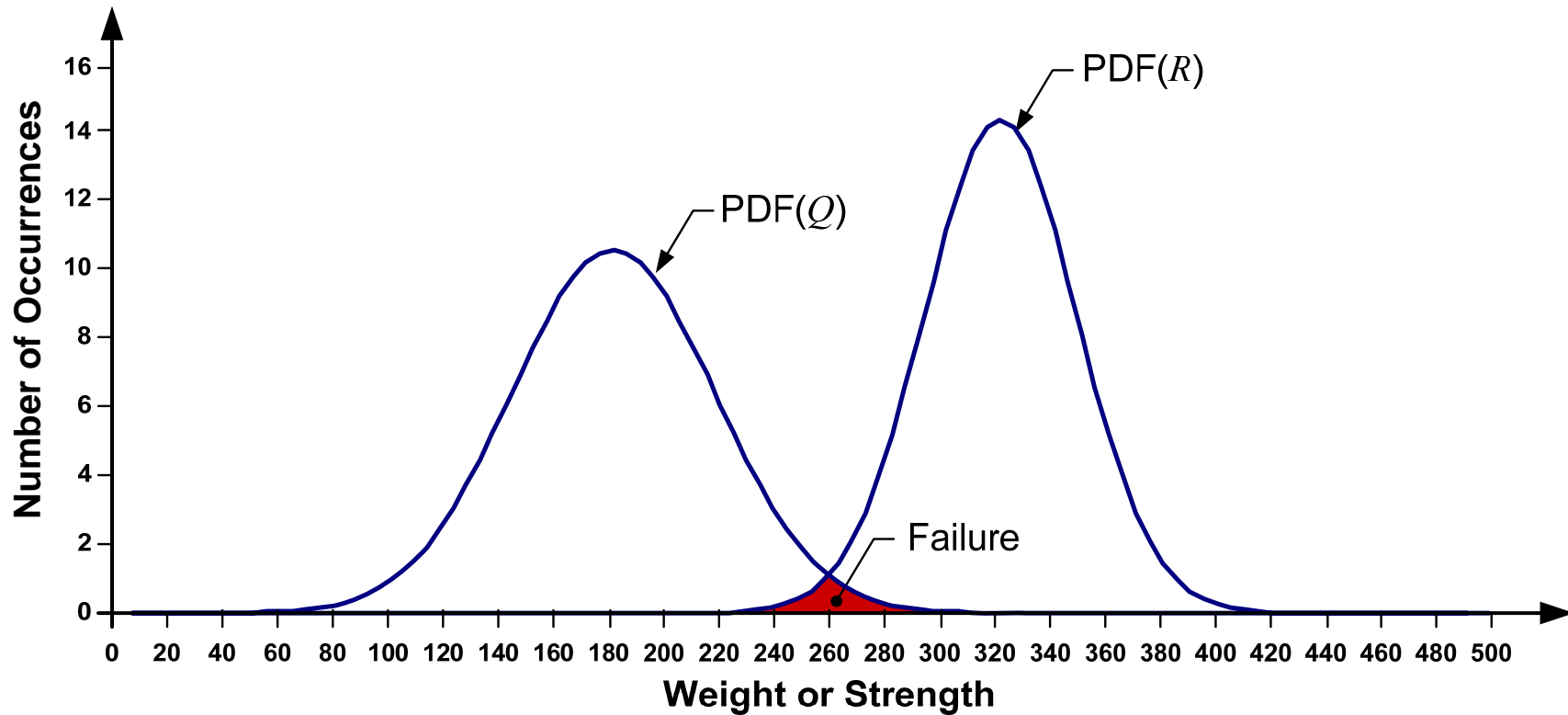
Weight	Number of Samples
320	15
330	14
340	11
350	8
360	5
370	3
380	2
390	0
400	1
410	0
420	0



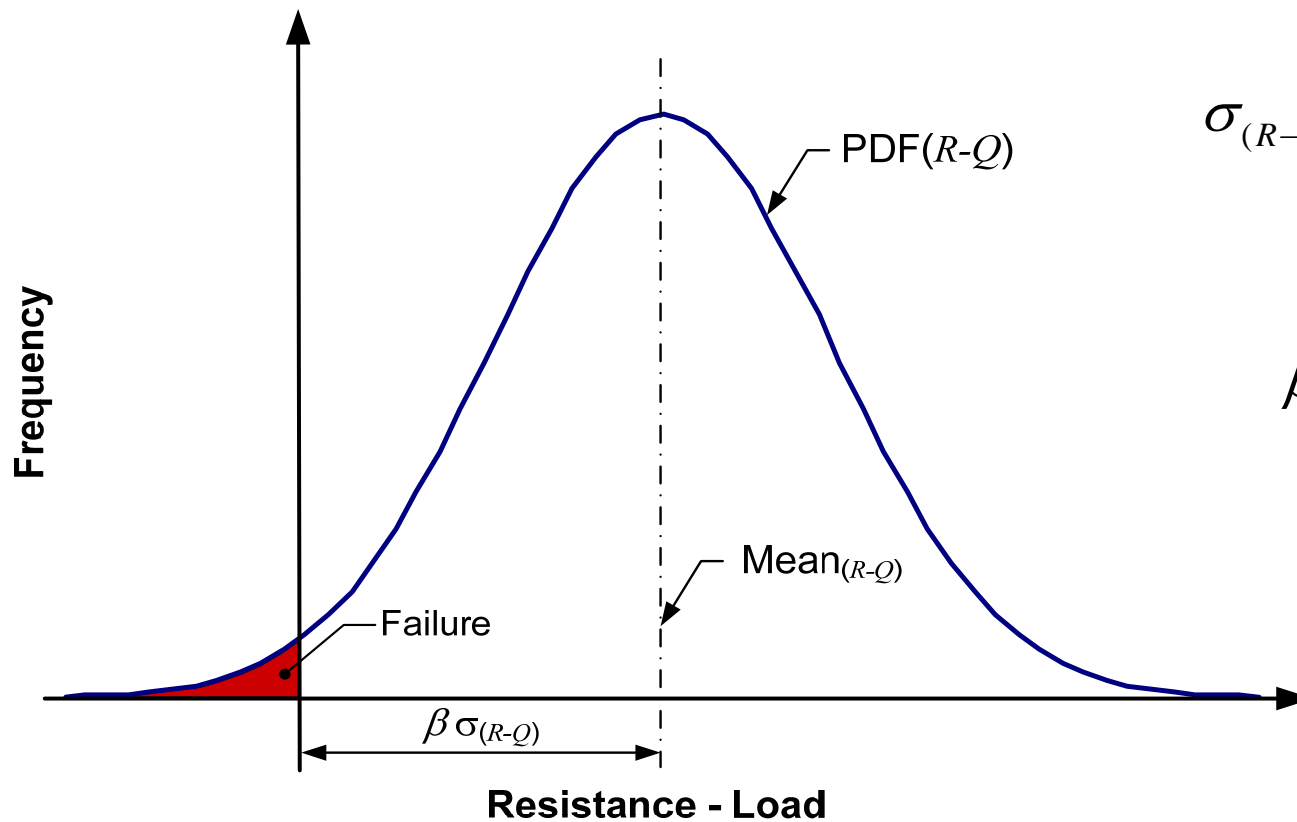
**Average = 320<sup>lbs</sup>**

**St Deviation = 28<sup>lbs</sup>**

# Variability of Loads and Resistances:



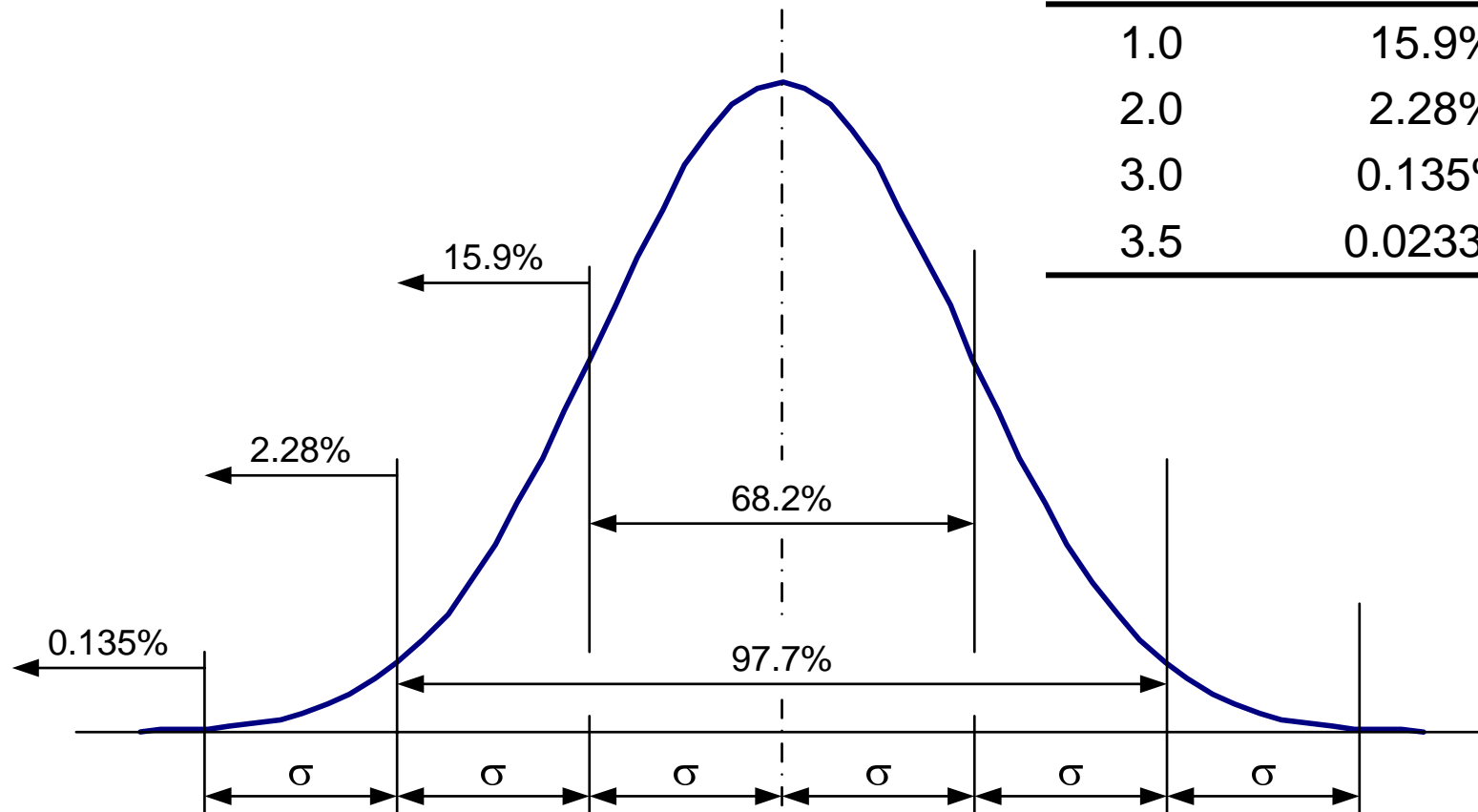
# Variability of Loads and Resistances:



$$\sigma_{(R-Q)} = \sqrt{\sigma_R^2 + \sigma_Q^2}$$

$$\beta = \frac{\text{Mean}_{(R-Q)}}{\sigma_{(R-Q)}}$$

# Reliability Index:



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## Resistance Factor:

$$\phi = \frac{R_m}{R_n} e^{[-0.55\beta \text{ COV}(R_m)]}$$

- $R_m$  - Mean Value of  $R$  (from experiments)
  - $R_n$  - Nominal Value of  $R$  (from cross-sectional properties)
  - $\beta$  - Reliability Index
  - $\text{COV}(R_m)$  - Coeff. of Variation of  $R$
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# Expected Results...

- Statistical analysis is anticipated to prove that higher resistance factors can/should be used for high-strength fasteners
  - Larger resistance factor will make bolted connections more competitive in design applications (designs will be more economical than before)
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# Thank You!