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Load Resistance Factor Design (LRFD) and Allowable Stress Design (ASD)

Different Ways of Looking at the Same Thing

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Uncertainties in Design

- Uncertainty exists in everything we design
- We compensate for these uncertainties in our design codes
- The way in which we compensate is different between LRFD and ASD

Uncertainty - LRFD

- Uncertainties are handled in LRFD design codes through:
  - Nominal Capacities
    - for uncertainties in material properties, construction tolerances, and
  - Resistance Factors
    - for uncertainties in variable loads

Uncertainty - ASD

- Uncertainties are handled in ASD design codes through:
  - Factor of Safety
    - a single variable is used to handle uncertainty in both load and capacity

Additional Uncertainties

- Design errors
- Construction errors
- These cannot be incorporated into the design codes but are addressed through proper quality assurance techniques

Categories of Uncertainty

- Aleatory
  - Dependent upon luck or chance
  - Randomness inherent in nature
- Epistemic
  - Dependent upon human knowledge
  - This may be reduced by increasing the profession's knowledge about the area of interest

Types of Probability

- Frequentist
  - What we commonly think of with probability
  - A coin flipped 10,000 times comes up heads H times, the probability is H/10,000 of flipping heads on that particular coin
- Subjective
  - A coin has two sides, each side appears to have an equal chance of landing up, therefore the probability is ½ for getting one side versus the other.

Return periods

- Loads caused by earthquakes or flood events are based on return periods (say 50 years)
  - On average, an event will occur once every 50 years
  - What is the probability that in 50 years the load will be exceeded?

Random Variables

- Material properties are considered random variables
- The compressive strength of concrete will vary between cylinders within a batch and between batches
- Probability distributions (such as a normal, log normal, or Weibull curves) represent material properties even though we design with a specific value

Causes of Uncertainty

- Time
  - What weight/configuration will a truck have in 30 years
- Statistical Limits
  - How many cores are needed to represent the roadway
- Model Limits
  - Simplifications used for design
- Randomness
  - Properties of random variables (material properties)
- Human Error
  - Errors during design or construction

How we Handle Uncertainty in Design

- The change from ASD to LRFD was proposed in the late 70's, early 80's because of LRFD's ability to better handle certain sources of uncertainty

ASD

- The general form for ASD is:

$$\frac{R_n}{FS} \geq Q_d + \gamma(Q_{t1} + Q_{t2})$$

where:

- R_n = nominal resistance
- Q_d = nominal dead load effect
- Q_{t1}, Q_{t2} = nominal transient load effects
- γ = load combination factor
- FS = Factor of Safety

LRFD

- The general form for LRFD is:

$$\phi R_n \geq \gamma_d Q_d + \gamma_{t1} Q_{t1} + \gamma_{t2} Q_{t2}$$

where

- Rn = nominal resistance
- Qd = nominal dead load effect
- Qt1, Qt2 = nominal transient load effects
- γ1 = load factor associated with the ith load effect
- Φ = resistance factor

Calibration of LRFD to ASD

- The ASD codes contained a large amount of implicit design knowledge
- Calibration transfers the risk society is willing to accept with regard to structural failures (ASD evolved overtime to include this)
- Structural engineers are more comfortable with small changes

Uncertainty Reduction

- Use load and reduction calculation techniques
- Check designs and inspect construction
- Make appropriately conservative assumptions
- Check complex analyses with more simple methods
- Use your own experience

Reference

- Bulleit, William M. “Uncertainty in Structural Engineering”. Practice Periodical on Structural Design and Construction. American Society of Civil Engineers (ASCE), February 2008, pp 24 – 30.