AASHTO LRFD Bridge Code Calibration

A Research Project by:

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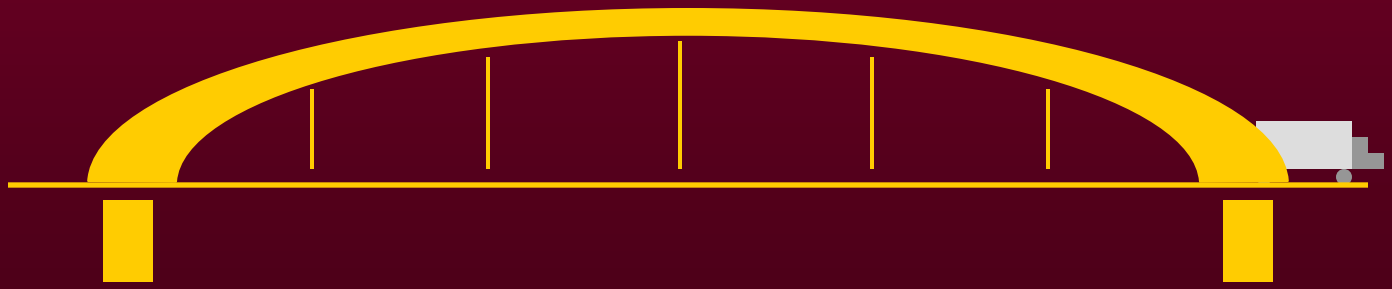

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The Problem

- Inaccurate estimation of fatigue effects on bridges

What needs to be done

- Calibration of the fatigue-and-fracture limit state

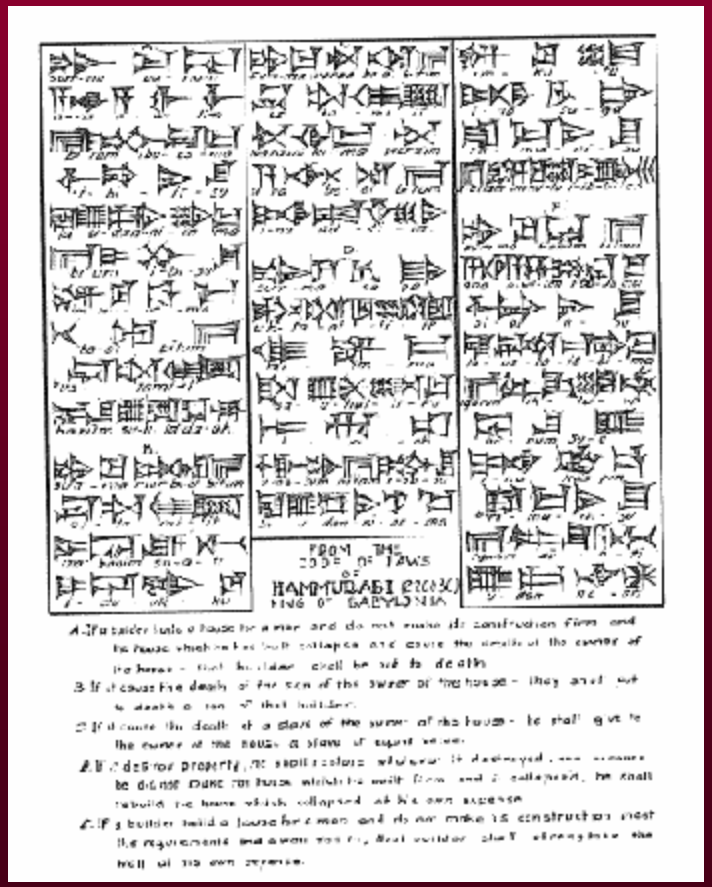
Proposed Solution

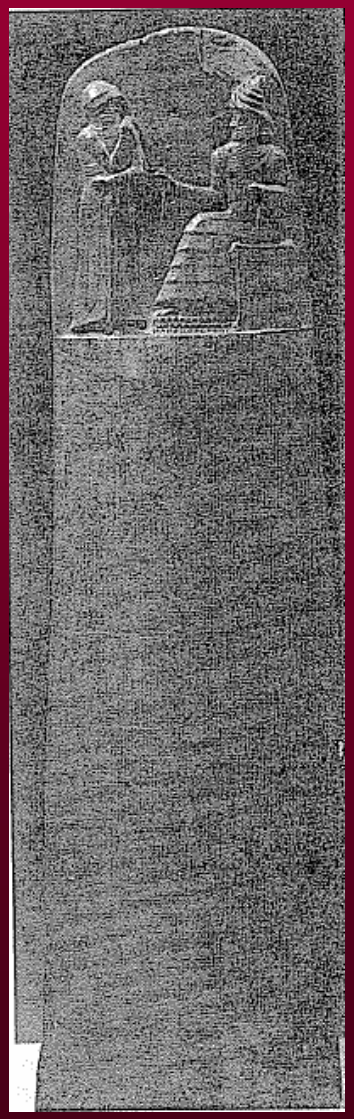
- Evaluation of calibration of strength limit state and comparison to fatigue – fracture limit state

History of Safety Code
Ancient Engineering

Code of Hammurabi

- An eye for an eye almost…





History of Safety Code
Modern Engineering

ASD - Working stress design

$\varphi/\gamma R_n \geq \Sigma Q_i$

LFD - Limit State Design

φ (maximum Strength) $\geq \gamma[\beta_D + \beta_L(L+I)]$

LRFD - Probability-based Limit State Design

$\varphi R_n \geq \Sigma \gamma_i Q_i$

Calibration of Strength Limit State

Calibration Procedure (Nowak 1995)

1. Selection of Representative Bridges
2. Establishment of Statistical Database for Load and Resistance parameters
3. Development of Load and Resistance Models
4. Development f Reliability Analysis Procedure
5. Selection of Target Reliability index
6. Calculation of Load and Resistance Factors

1. Selection Of Representative Bridges

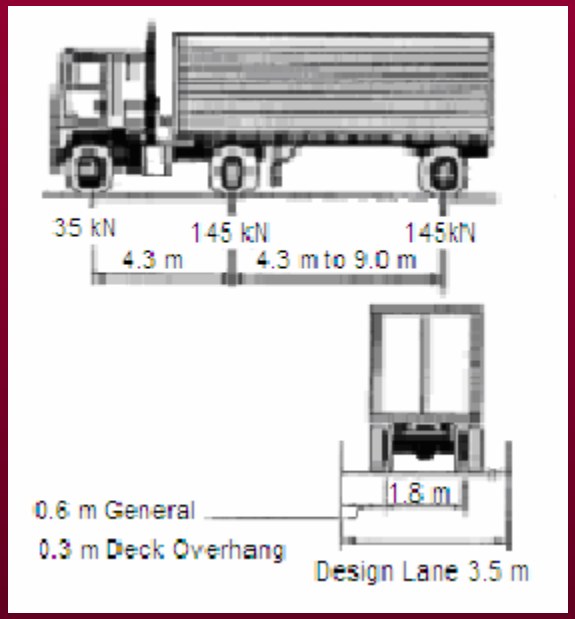
- Over 200 bridges
  - Variety
    - Bridge Type
    - Location

2. Establishment of Statistical Data base

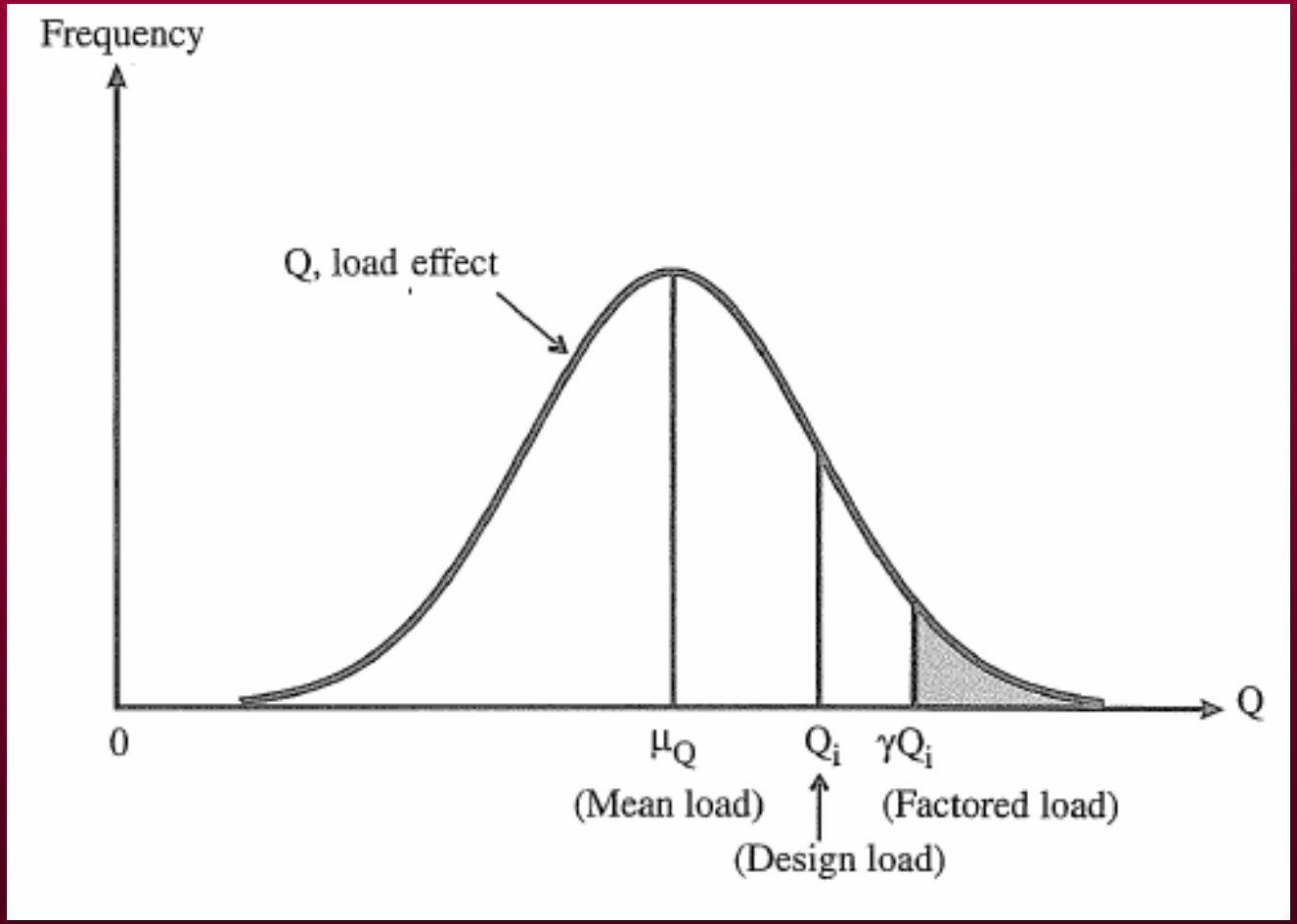
- Load
  - Weigh in Motion
  - Truck surveys
  - Numerical procedures
- Resistance
  - Tests
  - Numerical Procedures

3a. Development of Load model

- Dead and Live Load
  - Design Truck
    - HS20
    - HL93 = HS20 + Lane load (9.3 kN/m)
- Girder Distribution Factor
  - S/D
  - GDF = $0.15 + (s/3)^{0.6}(s/Span)^{0.2}$



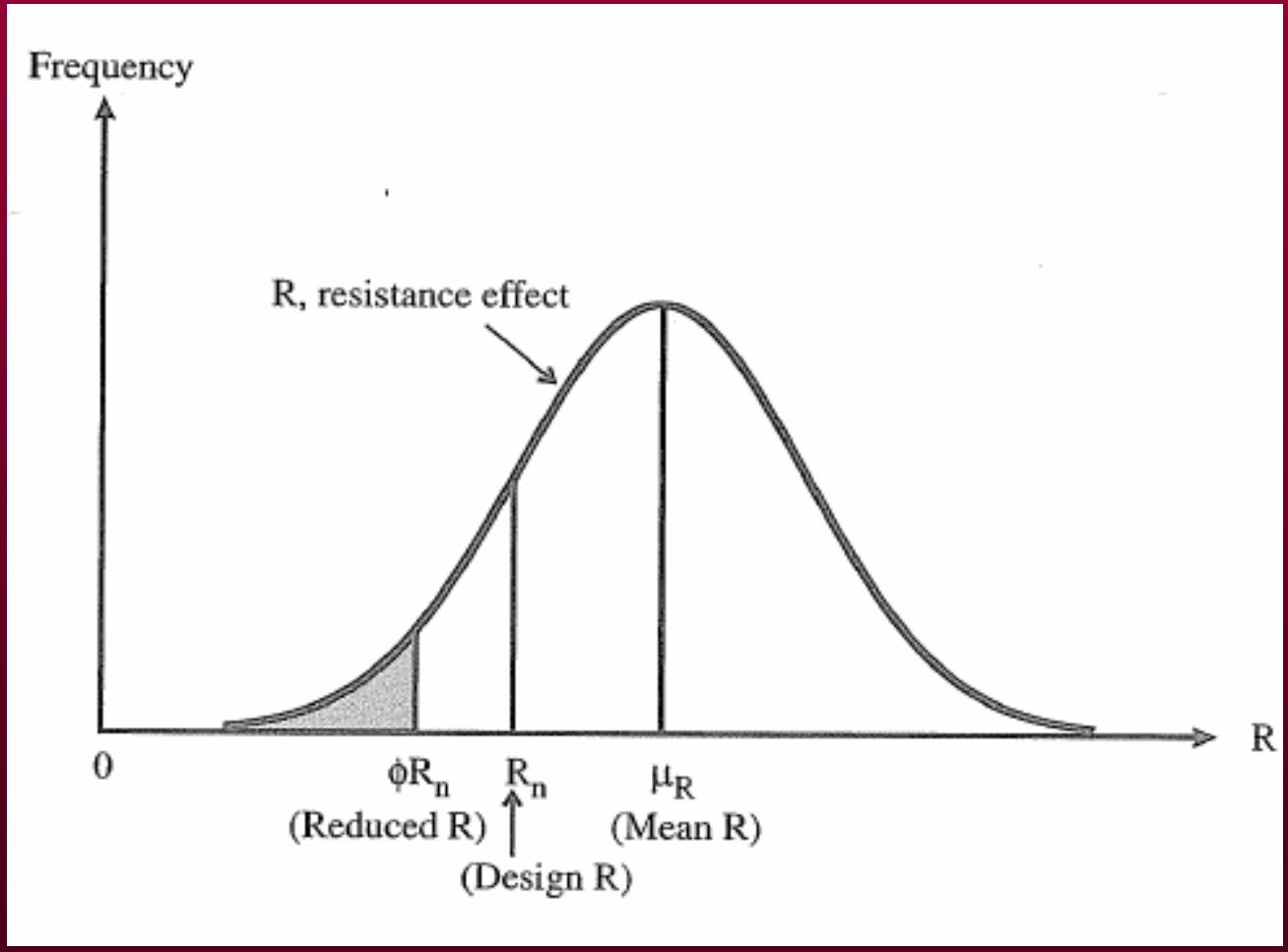
Load Model PDF



3b. Development of Resistance Model

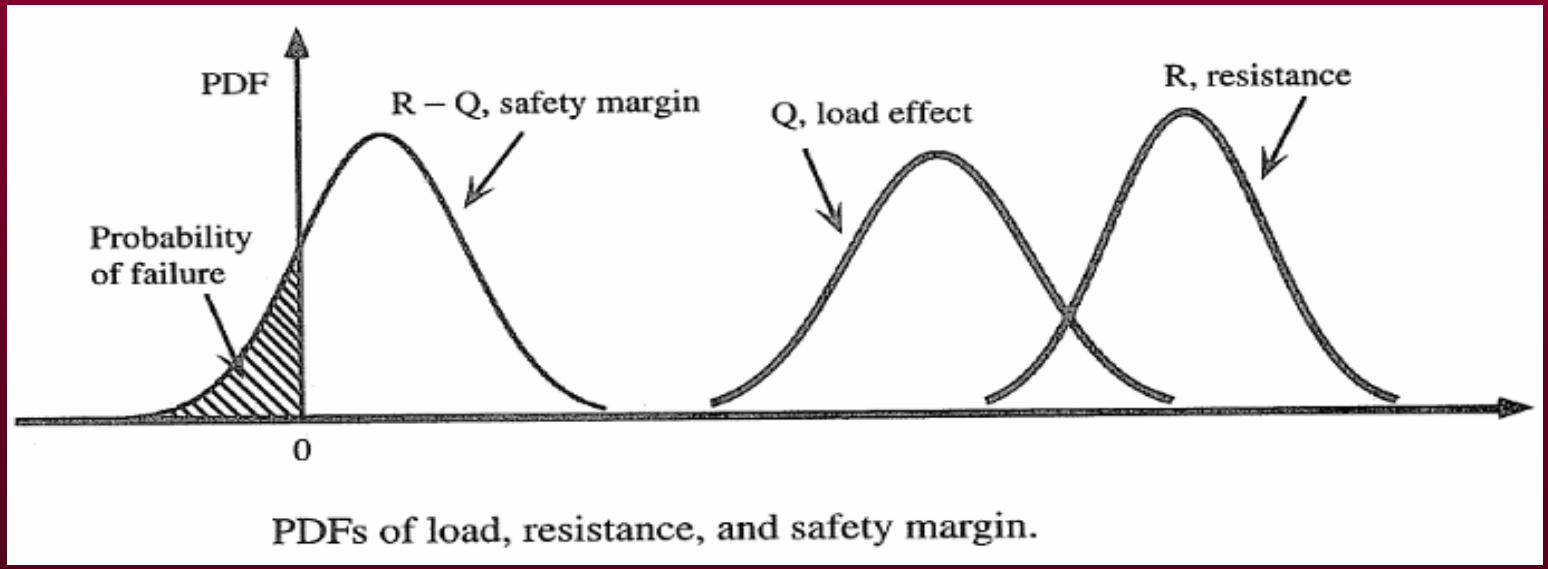
- $R = R_n MFP$
  - Rn = Nominal Resistance
  - M = Material
  - F = Fabrication
  - P = Professional / Analysis
- $V_R = (V^2_M + V^2_F + V^2_P)^{1/2}$
  - V = Respective Coefficient of Variation

Resistance Model PDF



4. Development of Reliability Analysis Procedure

- Limit State Function
  - g = R-Q
    - R and Q random variables

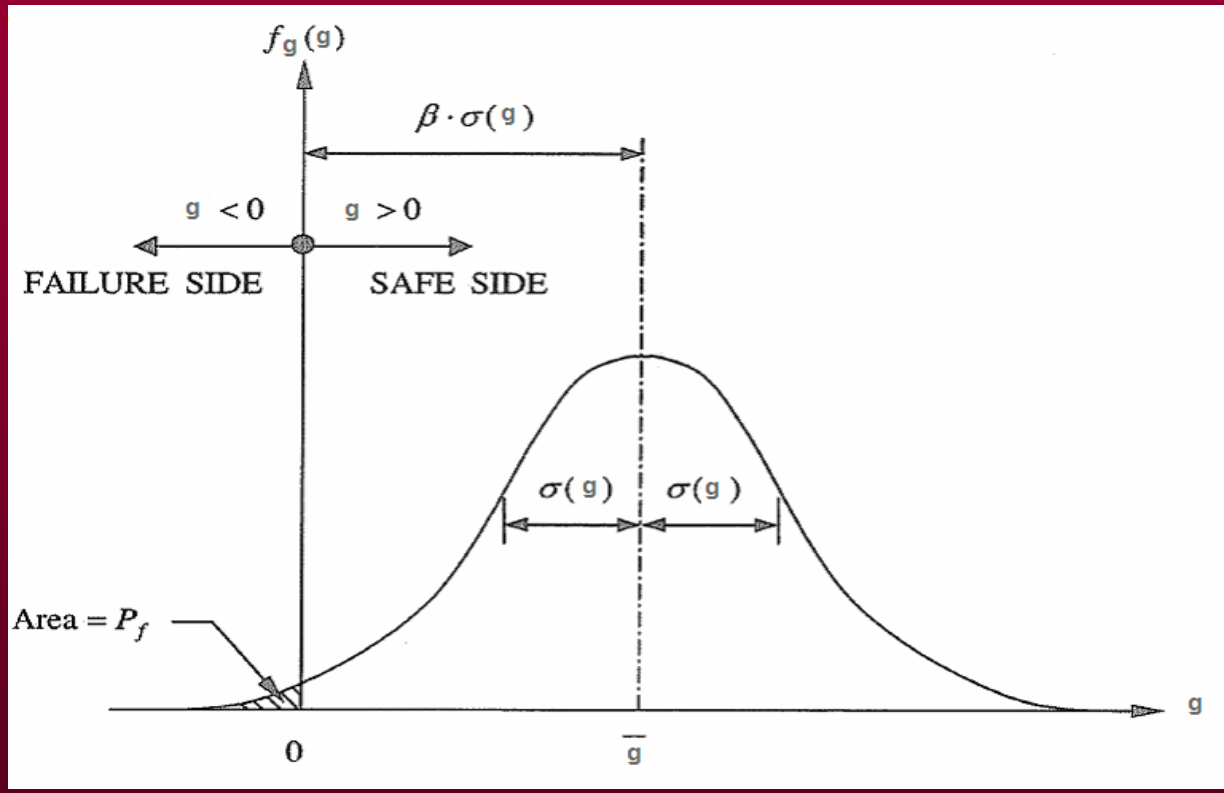


PDFs of load, resistance, and safety margin.

- Probability of Failure
  - P_f= Prob(R-Q<0) = Prob(g<0)

4. Development of Reliability Analysis Procedure

PDF for g
(safety margin)



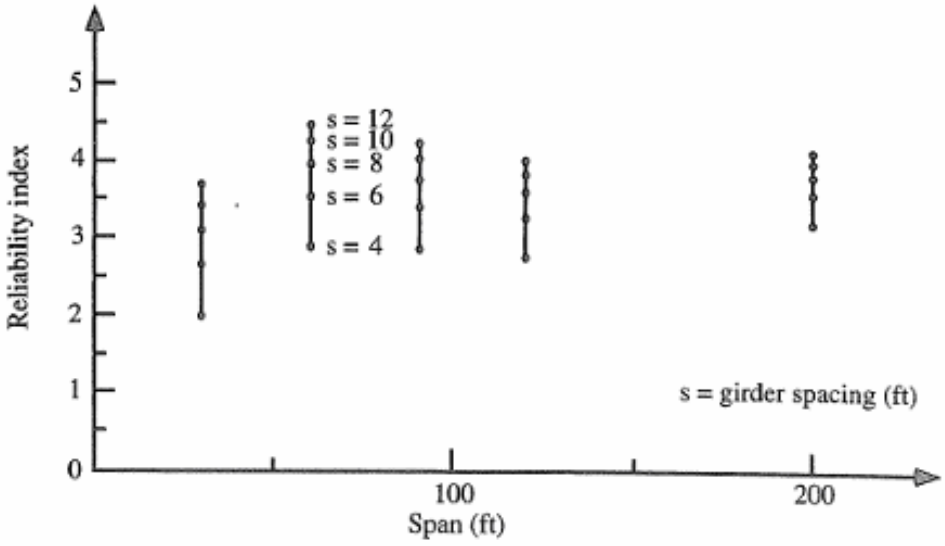
- Definitions of β

  β is a measure of the safety of the structure.

  - $\beta = 1/V = \mu/\sigma$
  - $\beta = (R_m - Q_m) / (\sigma^2_R + \sigma^2_Q)^{1/2}$
  - $\beta = -\varphi^{-1}(P_f)$
  - ➢ $\beta = [R_n \lambda_R(1-kV_R)[1-\ln(1-kV_R)-Q_m] / \{[(R_n V_R \lambda_R(1-kV_R)]^2+\sigma^2_Q\}^{1/2}$

5. Selection of Target Reliability Index

- Previous Design Equation
  - $\varphi R > 1.3D + 2.17(1+I)L$



Reliability indexes for steel girders, bending limit state (AASHTO, 1992).

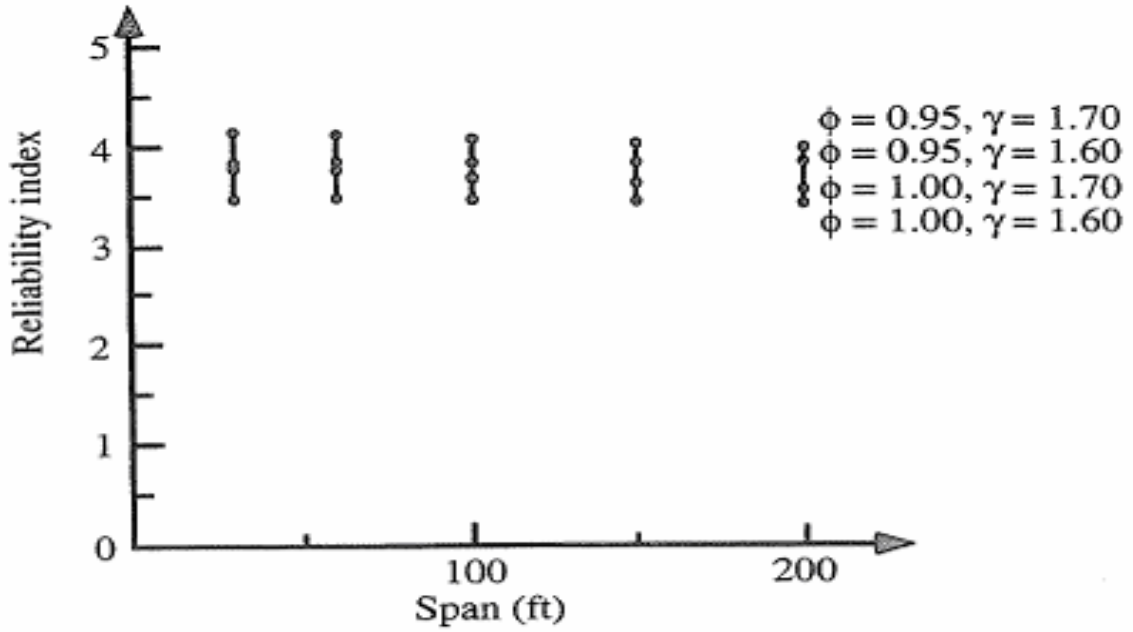
  - $\beta_T = 3.5$ chosen

6. Calculation of Load and Resistance Factors Bridges

- Load factor relationship to bias factor for each load case
  - $\gamma_i = \lambda_i (1 + kV_i)$
    - λi = Bias factor (ratio of mean to nominal)
    - k= 2 in practice

- New Strength Design Equation
  - $\varphi R > 1.25D + 1.50D_A + 1.70(L+I)$
    - D = Dead Load
    - D_A = Asphalt Load
    - L + I = Live + Impact
    - φ = 1.00 for flexure and shear

5. Target Reliability Index: New equation



Reliability indexes for steel girders, bending limit state (new code).

Results

- Better consistency in safety margins
- Better representation of reality through use of probability
- More economical designs
- Incorporation of new research

Comparison

Strength

1. Relatively easy to simplify
2. Limited uncertainties applied
   - g=R-Q
3. Units of strength, ksi
4. Dependant on one max load
5. History of bridge not as crucial
6. Immediate Testing available

Fatigue-fracture

1. Very complicated
2. More uncertainties
   - $(N/A)E(S^B) - \Delta = 0$
3. Dependant on time, n or t
4. Stress range: Varying amplitude needs to be accounted for (even order)
5. Fatigue is cumulative
6. Difficulty collecting data for parameters

Recommendations

- Further research on fatigue
- Thorough understanding of reliability and statistical procedures and theory

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Questions?