Philosophy of Loads & Resistance Factored Design (LRFD)

1- Loads are different in;

- Nature and type

- **Dead loads (D) : are constant in magnitude and remain in one direction, consist of own weight of structure (steel weight, walls, floors, roof, utility pipes, etc)**

- **Live loads (L) : may change in position and magnitude, also can be movable loads as trucks and cranes.**
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- **Environmental loads: caused by the environment in which a particular structure is located and it varied with time and may not all act all together, as;**
  - **(a) Snow (S)**
  - **(b) Rain (R)**
  - **(c) Temperature change (T)**
  - **(d) Wind loads (W)**
  - **(d) Earthquake loads (E)**

- Magnitude

The minimum design loads for buildings and other structures are specified by the applicable codes, as the American Society of Civil Engineering (ASCE 7-98)

- Load Factors

Load factors are used to increase the magnitude of the calculated loads to account for the uncertainties involved in estimating the magnitude of different loads as, dead, live, wind and earthquake loads. Load factors are different according to the load nature, and its applied period.

For Example, dead load factor = 1.4
Live load factor = 1.6

- Load Combinations

Different types of loads can be combined since it can be applied simultaneously, however they may not be with the same magnitudes and factors.
For example, it is very rarely that the structure will be subjected to the total factored dead and live loads at the same instant the factored wind load or the earthquake loads will be maximum.

The following load combinations are used to investigate the critical combination of factored loads (ultimate loads = P_u):

1- 1.4D
2- 1.2D + 1.6 (L, or S or R)
3- 1.2D + 1.6 (L_r, or S or R) + (0.5L or 0.8W)
4- 1.2D ± 1.6W + 0.5L + 0.5 (L_r, or S or R)
5- 1.2D ± 1.0E + 0.5L + 0.2S
6- 0.9D ± (1.6 W or 1.0E)

2- Resistance

Resistance of a member is it's nominal strength based on it' s nominal dimensions, and material properties.

- Resistance Factors

Are used to reduce the nominal strength (P_n) to account for the uncertainties in the material strength, dimensions, workmanship and consequences of failure.

Some examples of the strength reduction factor (resistance factor), Φ, are :

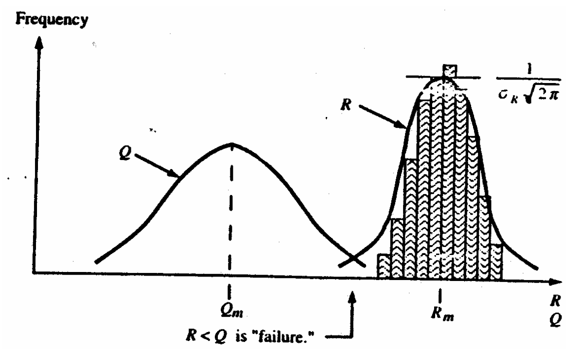
1. Φ_c = 0.85 for axial compression and columns
2. Φ_v = 0.90 for shear in beams
3. Φ_b = 0.90 for flexure in beams (bending moment)
4. Φ_t = 0.90 for yielding in a tension member
5. Φ_t = 0.75 for fracture in a tension member, welds & bolts

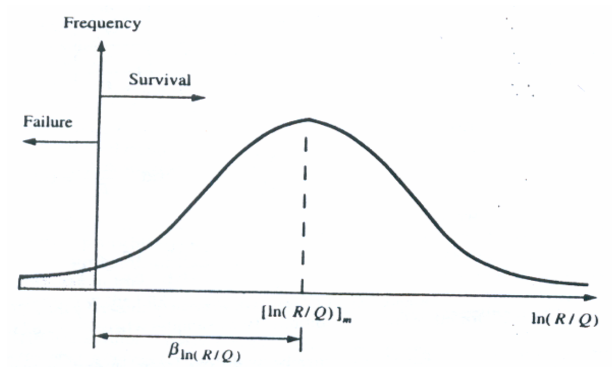
3- Reliability and LRFD Specification

- Reliability is refered to the estimated percentage of times that the resistance of a structure will equal or exceed the maximum loading combination applied to the structure during its estimated life (say 50 years)

Usually steel structures are designed to be 99.7% reliable, then only a probability of 0.3% the strength will be lower than the applied loads, but it doesn't mean failure !!!

The typical distribution of the Resistance (R) of a member and the applied loads (Q) are varied and as shown to be normal distribution





β **: reliability Index = number of standard deviations from the mean**

$$\beta = \frac{\ln(R_m / Q_m)}{\sqrt{V_R^2 + V_Q^2}}$$

β= 1.75 for member subjected to gravity loads and earthquake loads
β = 2.50 for member subjected to gravity loads and wind loads
β = 3.00 for members subjected to gravity loads
β = 4.50 for connections (bolts and weld)

Therefore the resistance factors (**Φ**) for different members and load factors for different load combinations are adjusted accordingly to be as mentioned before.

LRFD target is to satisfy the following condition

Factored Resistance ≥ Factored Loads

$$\Phi P_n \geq P_u$$