Chapter 14

DESIGN PHILOSOPHIES of ACI and AISC CODES

14.1 Safety Provisions

1 Structures and structural members must always be designed to carry some reserve load above what is expected under normal use. This is to account for

Variability in Resistance: The **actual** strengths (resistance) of structural elements will differ from those **assumed** by the designer due to:

1. Variability in the strength of the material (greater variability in concrete strength than in steel strength).
2. Differences between the actual dimensions and those specified (mostly in placement of steel rebars in R/C).
3. Effect of simplifying assumptions made in the derivation of certain formulas.

Variability in Loadings: All loadings are variable. There is a greater variation in the live loads than in the dead loads. Some types of loadings are very difficult to quantify (wind, earthquakes).

Consequences of Failure: The consequence of a structural component failure must be carefully assessed. The collapse of a beam is likely to cause a localized failure. Alternatively the failure of a column is likely to trigger the failure of the whole structure. Alternatively, the failure of certain components can be preceded by warnings (such as excessive deformation), whereas other are sudden and catastrophic. Finally, if no redistribution of load is possible (as would be the case in a statically determinate structure), a higher safety factor must be adopted.

2 The purpose of safety provisions is to limit the **probability of failure** and yet permit economical structures.

3 The following items must be considered in determining safety provisions:

1. Seriousness of a failure, either to humans or goods.

$$\boxed{\sigma < \sigma_{all} = \frac{\sigma_{yld}}{F.S.}} \tag{14.1}$$

where $F.S.$ is the factor of safety.

10 Major limitations of this method

1. An elastic analysis can not easily account for creep and shrinkage of concrete.
2. For concrete structures, stresses are not linearly proportional to strain beyond $0.45f'_c$.
3. Safety factors are not rigorously determined from a probabilistic approach, but are the result of experience and judgment.

11 Allowable strengths are given in Table 14.1.

Steel, AISC/ASD	
Tension, Gross Area	$F_t = 0.6F_y$
Tension, Effective Net Area*	$F_t = 0.5F_u$
Bending	$F_b = 0.66F_y$
Shear	$F_v = 0.40F_y$
Concrete, ACI/WSD	
Tension	0
Compression	$0.45f'_c$

* Effective net area will be defined in section 17.2.1.2.

Table 14.1: Allowable Stresses for Steel and Concrete

14.3 Ultimate Strength Method

14.3.1 The Normal Distribution

12 The normal distribution has been found to be an excellent approximation to a large class of distributions, and has some very desirable mathematical properties:

1. $f(x)$ is symmetric with respect to the mean μ.
2. $f(x)$ is a "bell curve" with inflection points at $x = \mu \pm \sigma$.
3. $f(x)$ is a valid *probability distribution function* as:
$$\int_{-\infty}^{\infty} f(x) = 1 \tag{14.2}$$
4. The *probability* that $x_{min} < x < x_{max}$ is given by:
$$P(x_{min} < x < x_{max}) = \int_{x_{min}}^{x_{max}} f(x)dx \tag{14.3}$$

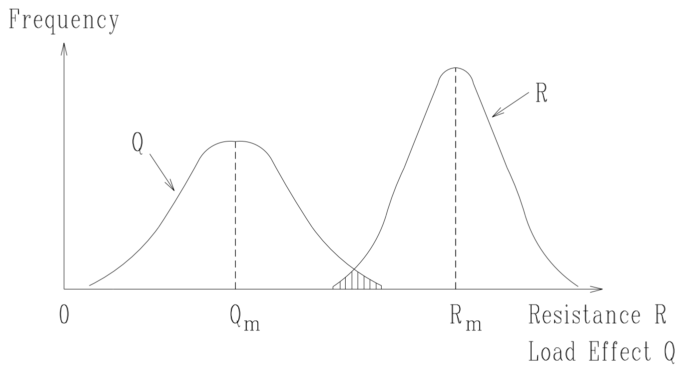

Figure 14.3: Frequency Distributions of Load Q and Resistance R

Failure would occur for negative values of X

19 The **probability of failure** P_f is equal to the ratio of the shaded area to the total area under the curve in Fig. 14.4.

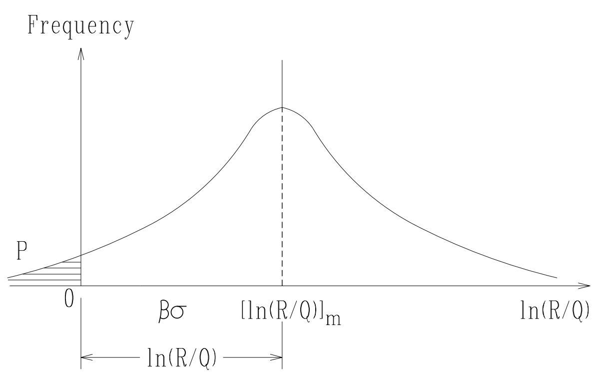

Figure 14.4: Definition of Reliability Index

20 If X is assumed to follow a **Normal Distribution** than it has a mean value $\overline{X} = \left(\ln \frac{R}{Q}\right)_m$ and a standard deviation σ.

21 We define the **safety index** (or **reliability index**) as $\beta = \frac{\overline{X}}{\sigma}$

22 For standard distributions and for $\beta = 3.5$, it can be shown that the probability of failure is $P_f = \frac{1}{9{,}091}$ or 1.1×10^{-4}. That is 1 in every 10,000 structural members designed with $\beta = 3.5$ will fail because of either excessive load or understrength sometime in its lifetime.

23 Reliability indices are a relative measure of the current condition and provide a qualitative estimate of the structural performance.

24 Structures with relatively high reliable indices will be expected to perform well. If the value is too low, then the structure may be classified as a hazard.

25 Target values for β are shown in Table 28.2, and in Fig. 28.3