Introduction into design engineering week 12

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Selection of an Appropriate factor of Safety

- The selection of the factor of safety to be used for various applications is one of the most important engineering tasks.
- On the one hand, if a factor of safety is chosen too small, the possibility of failure becomes unacceptably large; on the other hand, if a factor of safety is chosen unnecessarily large, the result is an uneconomical or nonfunctional design.

- The choice of the factor of safety that is appropriate for a given design application requires engineering judgment based on many considerations, such as the following:

1. ***Variations that may occur in the properties of the member under consideration.***

The composition, strength, and dimensions of the member are all subject to small variations during manufacture.

In addition, material properties may be altered and residual stresses introduced through heating or deformation that may occur during manufacture, storage, transportation, or construction.

2. ***The number of loadings that may be expected during the life of the structure or machine.***

For most materials the ultimate stress decreases as the number of load applications is increased.

This phenomenon is known as <u>*fatigue*</u> and, if ignored, may result in sudden failure.

3. *The type of loadings that are planned for in the design, or that may occur in the future.*

Very few loadings are known with complete accuracy – most design loadings are engineering estimates.

In addition, future alterations or changes in usage may introduce changes in the actual loading.

Larger factors of safety are also required for dynamic, cyclic, or impulsive loadings.

4.The type of failure that may occur.

Brittle materials fail suddenly, usually with no prior indication that collapse is imminent.

On the other hand, ductile materials, such as structural steel, normally undergo a substantial deformation called ***yielding*** before failing, thus providing a warning that overloading exist.

4.The type of failure that may occur.

However, most buckling or stability failures are sudden, whether the material is brittle or not.

When the possibility of sudden failure exists, a large factor of safety should be used than when failure is preceded by obvious warning signs.

5.Uncertainty due to methods of analysis

All design methods are based on certain simplifying assumptions which result in calculated stresses being approximations of actual stresses.

6. ***Deterioration that may occur in the future because of poor maintenance or because of unpreventable natural causes.***

A large factor of safety is necessary in locations where conditions such as corrosion and decay are difficult to control or even to discover.

7.The importance of a given to the integrity of the whole structure.

Bracing and secondary members may in many cases be designed with a factor of safety lower than that used for primary members.

- In addition to the above considerations, there is the additional consideration concerning the risk to life and property that a failure would produce.
- Where a failure would produce no risk to life and only minimal risk to property, the use of a smaller factor of safety can be considered.

- Finally, there is the practical consideration that, unless a careful design with a nonexcessive factor of safety is used, a structure or machine might not perform its design function.
- For example, high factors of safety may have an unacceptable effect on the weight of an aircraft.

- For the majority of structural and machine applications, factors of safety are specified by design specifications or building codes written by committees o experienced engineers working with professional societies, with industries or with federal, state, or city agencies.

- Examples of such design specifications and building codes are

1. ***Steel***; American Institute of Steel Construction, Specification for Structural Steel Buildings.

2. ***Concrete***; American Concrete Institute, Building Code Requirement for Structural Concrete

3. ***Timber***; American Forest and Paper Associtaion, National Design Specification for Wood Construction.

4. ***Highway Bridges***; American Association of State Highway Officials, Standard Specifications for Highway Bridges.

Load and Resistance Factor Design

- The allowable-stress method requires that all the uncertainties associated with the design of a structure or machine element be grouped into a single factor of safety.
- An alternative method of design, which is gaining acceptance chiefly among structural engineers, makes it possible through the use of three different factors to distinguish between the uncertainties associated with the structure itself and those associated with the load it is designed to support.

- This method, referred to as ***Load and Resistance Factor Design (LRFD)***, further allows the designer to distinguish between uncertainties associated with the *live load*, $\boldsymbol{P_L}$, that is with the load to be supported by the structure, and the *dead load*, $\boldsymbol{P_D}$, that is, with the weight of the portion of structure contributing to the total load.

- When this method of design is used, the *ultimate load*, $\boldsymbol{P_U}$, of the structure, that is, the load at which the structure ceases to be useful, should first be determined.
- The proposed design is then acceptable if the following inequality is satisfied:

$$\gamma_D P_D + \gamma_L P_L \leq \phi P_U \qquad (1.26)$$

$$\gamma_D P_D + \gamma_L P_L \leq \phi P_U$$

- The coefficient Φ is referred to as the ***resistance factor***; it accounts for the uncertainties associated with the structures itself and will normally be less than 1.
- The coefficients γ_D and γ_L are referred to as the ***load factors***; they account for the uncertainties associated, respectively, with the dead and live load and will normally be greater than 1, with γL generally larger than γD.