

# CE 382

## Structural Analysis

- Blue text is important course material
- Green text is important definition material for the course
- Red text is important conclusion or caution material for the course

**Text in bold is more significant than non-bolded text**

# STRUCTURAL ANALYSIS

As a structural engineer, you will be required to make many technical decisions about structural systems. These decisions include:

(1) selecting an efficient, economical and attractive structural form;

(2) evaluating structural safety, that is, its strength and stiffness; and

(3) planning the erection of the structure under temporary construction loads.

In order to perform structural design, you need to learn to carry out structural analyses.

**Structural analysis involves the prediction of the performance of a given structure under prescribed loads and/or other external effects, such as support movements and temperature changes.**

**The fundamental purpose of a structural analysis is to determine the magnitudes of force and displacement for each element of a design system for a given set of design loads.**

**Force is used to represent stresses or stress resultants**, e.g., axial forces, shear forces, bending moments, and torsional moments along with their associated stresses.

Designers determine the internal forces in key members in order to size both members and the connection between members.

Deflection calculations are carried out to ensure a **serviceable structure** – one that does not deflect or vibrate excessively under load such that structural function is impaired.

Stated differently, **structural engineering is the science and art of planning, designing, and constructing economical structures that can safely resist the forces to which they are subjected to with elegance.**

# Structural Analysis/Design Flowchart

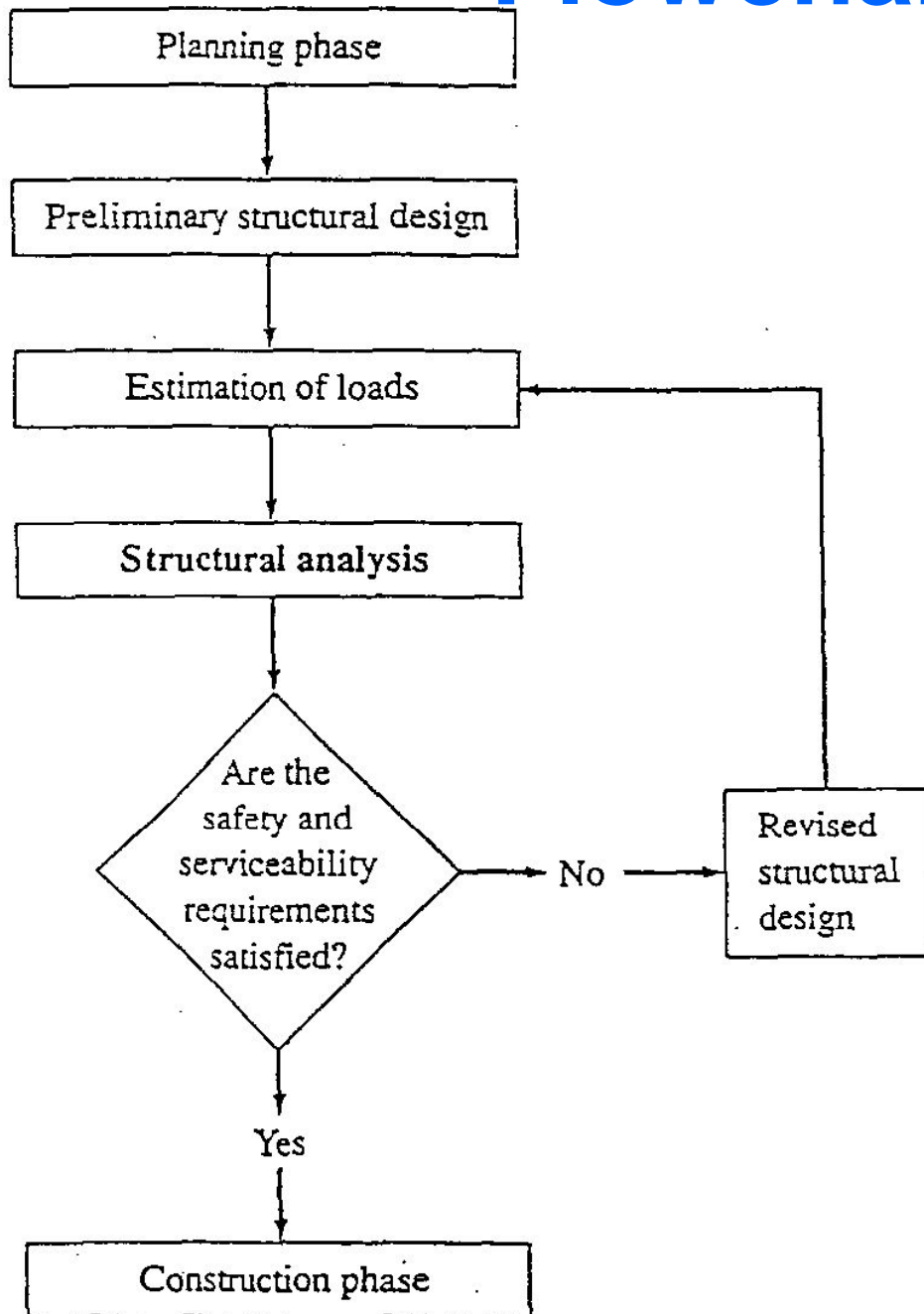


Fig. 1.2 Phases of a Typical Structural Engineering Project

# DESIGN OBJECTIVES

**Factors which influence design include: safety, serviceability, feasibility, and esthetics.**

**Safety** – Normally, **structural engineers design safely** in case something unforeseen or unknown happens. To properly assess safety, the structural engineer must:

- A.** Understand the environment, use of the structure, behavior of the construction materials, structural behavior, appropriate allowances for the uncertainty involved in the prediction of load effects and structural response, and any other influences that may influence the design or design performance.
  
- B.** Determine the internal forces and failure load.

A number of approaches to structural safety are possible. One method is referred to as ***Allowable Stress Design*** (ASD).

**ASD** is based on the assumption that if the stresses under working loads are limited to values substantially smaller than stresses corresponding to failure, then safety is assured.

Other approaches include: ***Ultimate Strength Design, Plastic Design, Load and Resistance Factor Design*** and others.

These **limit state** procedures incorporate safety by multiplying dead loads and live loads by load factors greater than one but less than two. The **live load factor is typically larger than the dead load factor since dead loads are more accurately assessed.**

Furthermore, all **design procedures typically reduce the load carrying capacity or strength parameters associated with the structure.**

Typically, the structural strength parameters are reduced by 0.60 to 0.90.

**Serviceability** – All aspects of performance must be acceptable for the intended use. Some specific performance considerations that the structural engineer must consider include: deflection and cracking must be limited, i.e., not visible; vibration and noise should be controlled; liquid and gas containers should not leak; foundations must not settle improperly; etc.

**Feasibility** – Construction of a proposed structure must be economical as well as plausible (feasible). A basic rule in design is that the designer should contemplate at least one method of construction. The structure may not be built in exactly the manner anticipated, but still the feasibility of the structure is assured.

**Esthetics (or Aesthetics)** – The looks of the structure are of great concern to the community and the designer.

# STRUCTURES

**Truss:** A truss is a geometrically stable arrangement of slender members which primarily support axial load.

**Frame:** A frame is a stable structural form consisting of two or more flexural members that can resist bending moment, shear, and axial forces. A frame is classified as a **rigid frame** when its members are joined together by moment resisting connections; i.e., where joint translations and rotations occur without relative rotations between the connected members.

**Arch:** The arch can be defined as a curved structural shape that is usually configured to support gravity loads in a manner that results in uniform compressive resistance. Gravity loading tends to flatten the arch and push its supports outward.

**Cable:** Cable supported structures are very common and are often expressed in the form of suspension and cable-stayed bridge construction.

**Membranes** are thin-walled structures such as air supported stadium roofs and weather balloons which provide tensile resistance in two directions.

**Flat plate structures** can provide bending, tensile, and compressive force resistance, e.g., floor slabs.

**Shells** are often defined as curved plates. Roof domes, water and fuel storage tanks, and grain silos typify some forms of shell structures.

# Computer Analysis

Most structural computer programs perform a **first-order analysis**: (1) linear elastic behavior, (2) member forces are unaffected by deformations (change of geometry) of the structure, and (3) no reduction in flexural stiffness.

Computer programs have tremendously reduced the labor of performing structural analysis and design.

**The designer must still possess basic insight into all potential failure modes in order to assess computer solution reliability.**

Furthermore, the **engineer must prepare a mathematical model that adequately represents the structure and the engineer must interpret the results correctly.**

# CE 382 Structural Calculations

- Prepare a clear sketch of the structure, showing all loads and dimensions.
- ***Include all steps of your computations.***
- ***Check your results.***

## **For computer generated results:**

Verify that the deflection directions are consistent with the applied forces – computer programs typically include post-processing features that include scaled displacement plots of the structure.