Design Basis

Two philosophies of design have long been prevalent. The working stress method, focusing on conditions at service load (that is, when the structure is being used), was the principal method used from the early 1900s until the early 1960s. The Strength Design or **Ultimate Strength Design** method selects concrete dimensions and reinforcements so that the member strength are adequate to resist forces resulting from certain hypothetical overload stages, significantly above loads expected actually to occur in service. The design concept is known as "**strength design**." Based on strength design the nominal strength of a member must be calculated on the basis of inelastic behavior of material. In other words, both reinforcing steel and concrete behave inelastically at ultimate strength condition.

"From the early 1900s until the early 1960s, nearly all reinforced concrete design in the United States was performed by the working-stress design method (also called allowable-stress design or straight-line design). In this method, frequently referred to as WSD, the dead and live loads to be supported, called working loads or service loads, were first estimated. Then the members of the structure were proportioned so that stresses calculated by a transformed area did not exceed certain permissible or allowable values.

"After 1963, the ultimate-strength design method rapidly gained popularity because (1) it makes use of a more rational approach than does WSD, (2) it uses a more realistic consideration of safety, and (3) it provides more economical designs. With this method (now called strength design), the working dead and live loads are multiplied by certain load factors (equivalent to safety factors), and the resulting values are called factored loads. The members are then selected so they will theoretically just fail under the factored loads. In 1956, the ACI Code for the first time included ultimate-strength design, as an appendix, although the concrete codes of several other countries had been based on such considerations for several decades. In 1963, the code gave ultimate-strength design equal status with working-stress design; the 1971 code made the method the predominant method and only briefly mentioned the working-stress method. From 1971 until 1999, each issue of the code permitted designers to use working-stress design and set out certain provisions for its application.

Beginning with the 2002 code, however, permission is not included for using the method." (Design of Reinforced Concrete by Jack C. McCormac and Russell H. Brown)

Working or Allowable Stress Design: As an alternate to the strength design method, members may be proportioned so that stresses in the steel and concrete resulting from normal service loads are within specified limits (an allowable, or permissible, stress or load). These limits, known as allowable stresses are only fractions of the failure stresses of the material. Allowable stress design is also referred to as "working stress design."

The working stress method may be expressed by the following

$$f \le allowable \quad stresses \quad (f_{allowable})$$

f = An elastically computed stress, such as by using the flexure formula $f = Mc/I$ for beam.

f_{allow} = A limiting stress prescribed by a building code as a percentage of the compressive strength f_c' for concrete, or of the yield stress f_y for the steel reinforcing bars.

History of WSD and USD Design methods

Change of Design Methods according to ACI 318 Code (PCA, 1999).
ACI 318-56: USD was first introduced (1956)
ACI 318-63: WSD and USD were treated on equal basis.
ACI 318-71: Based entirely on strength Method (USD)
WSD was called Alternate Design Method (ADM).
ACI 318-77: ADM relegated to Appendix B
ACI 318-89: ADM back to Appendix A
ACI 318-95: ADM still in Appendix A
Unified Design Provision was introduced in Appendix B
ACI 318-02: ADM was deleted from Appendix A (ACI,2002)

Differences between USD & WSD

WSD	USD
The members of the structure are proportioned so that stresses calculated by a transformed area did not exceed certain permissible or allowable values.	Select concrete dimensions and reinforcements so that the member strength are adequate to resist forces resulting from certain hypothetical overload stages, significantly above loads expected actually to occur in service. The design concept is known as “strength design.”
Loads are calculated within elastic limit.	Based on strength design the nominal strength of a member must be calculated on the basis of inelastic behavior of material. In other words, both reinforcing steel and concrete behave inelastically at ultimate strength condition..
No factors are used to multiply the working load.	working dead and live loads are multiplied by certain load factors (equivalent to safety factors),
Less economical than USD.	USD is more economical.