

## **1.5 CONCEPT OF WORKING STRESS METHOD, ULTIMATE LOAD DESIGN AND LIMIT STATE DESIGN METHODS FOR RCC**

Various methods used for the design of R.C.C. structures are as follows:

- (i) Working stress method.
- (ii) Load factor or ultimate load method.
- (iii) Limit state method.

### **Working Stress method**

This method of design was the oldest one. It is based on the elastic theory and assumes that both steel and concrete are elastic and obey Hooke's law. It means that the stress is directly proportional to strain up to the point of collapse. Based on the elastic theory, and assuming that the bond between steel and concrete is perfect, permissible stresses of the materials are obtained. The basis of this method is that the permissible stresses are not exceeded anywhere in the structure when it is subjected to worst combination of working loads.

In this method, the ultimate strength of concrete and yield strength or 0.2% proof stress of steel are divided by factors of safety to obtain permissible stresses. These factors of safety take into account the uncertainties in manufacturing of these materials. As per IS456, a factor of safety of 3 is to be used for bending compressive stresses in concrete and 1.78 for yield/proof strength of steel.

The main drawbacks of the working stress method of design are as follows :

- (i) It assumes that concrete is elastic which is not true as the concrete behaves in-elastically even on low level of stresses.
- (ii) It uses factors of safety for stresses only and not for loads. Hence, this method does not give true margin of safety with respect to loads because we do not know the failure load.
- (iii) It does not use any factor of safety with respect to loads. It means, there is no provision for the uncertainties associated with the estimation of loads.
- (iv) It does not account for shrinkage and creep, which are time dependent and plastic in nature.
- (v) This method gives uneconomical sections.
- (vi) It pays no attention to the conditions that arise at the time of collapse.

The working stress method is very simple and reliable but as per IS 456:2000 the working stress method is to be used only if it is not possible to use limit state method of design. Working stress method is the basic method and its knowledge is essential for understanding the concepts of design.

## Load Factor Method or Ultimate Load Method

In this method, ultimate or collapse load is used as design load. The ultimate loads are obtained by increasing the working/service loads suitably by some factors. These factors, which are multiplied by the working loads to obtain ultimate loads, are called as load factors. These load factors give the exact margins of safety in terms of load. This method used the real stress-strain curve of concrete and steel and takes into account the plastic behavior of these materials.

Many designers feel that the load factor provides a clear margin of safety and one can easily tell the load at which the structure fails, which is not clear from the working stress concept of permissible stresses. This method was given in detail in IS 456-1964,

The advantages of Ultimate load method are listed below:

- (i) The method is more realistic as compared to working stress method because ultimate load method taken into account the non-linear behavior of the concrete.
- (ii) This method gives exact margin of safety in terms of load unlike working stress method which is based on the permissible stresses which do not give any idea about the failure/collapse load.
- (iii) The sections designed by ultimate load method are thinner and require less reinforcement. Hence the method is economical as compared to WSM.

The main limitations of the ultimate load method are following:

- (i) This method gives very thin sections which leads to excessive deformations and cracking, thus making the structure unserviceable.
- (ii) No factors of safety are used for material stresses.

As the serviceability requirements are not satisfied at all in this method, the code replaced this method by limit state method which takes into account the strength as well as serviceability requirements.

## Limit State Method

This is the most rational method which takes into account the ultimate strength of the structure and also the serviceability requirements. It is a judicious combination of working stress and ultimate load methods of design. The acceptable limits of safety and serviceability requirements before failure occurs is called a limit state. This method is based on the concept of safety at ultimate loads (ultimate load method) and serviceability at working loads (working stress method).

The two important limit states to be considered in design are :

- (i) Limit state of collapse.
- (ii) Limit state of serviceability.

## Limit State of Collapse

This limit state corresponds to the strength of the structure and categorized into following types :

- (a) Limit state of collapse: Flexure.
- (b) Limit state of collapse: Shear and bond.
- (c) Limit State of collapse: Torsion.
- (d) Limit state of collapse: Compression.
- (2) Limit State of Serviceability

This limit state corresponds to the serviceability requirements i.e., deformation, cracking etc. It is categorized into following types:

- (a) Limit state of deflection.
- (b) Limit state of cracking
- (c) Limit state of vibration.

This method is based upon the probabilities variation in the loads and material properties. Limit state method takes into account the uncertainties associated with loads and material properties, thus uses partial factors of safety to obtain design loads and design stresses.

The limit state method is based on predictions unlike working stress method, which is deterministic in nature, assumes that the loads, factors of safety and material stresses are known accurately. In the limit state method, the partial safety factors are derived using probability and statistics and are different for different load combinations, hence giving a more rational and scientific design procedure.