FAQs:

1. **Explain the concept behind the limit state design method.**

   Limit states are the acceptable limits for the safety and serviceability requirements of the structure before failure occurs. The design of structures by this method will thus ensure that they will not reach limit states and will not become unfit for the use for which they are intended. It is worth mentioning that structures will not just fail or collapse by violating (exceeding) the limit states. Failure, therefore, implies that clearly defined limit states of structural usefulness have been exceeded.

   There are two main limit states: (i) limit state of collapse and (ii) limit state of serviceability.

   (i) Limit state of collapse deals with the strength and stability of structures subjected to the maximum design loads out of the possible combinations of several types of loads. Therefore, this limit state ensures that neither any part nor the whole structure should collapse or become unstable under any combination of expected overloads.

   (ii) Limit state of serviceability deals with deflection and cracking of structures under service loads, durability under working environment during their anticipated exposure conditions during service, stability of structures as a whole, fire resistance etc.

2. **Explain the term: Partial safety factor.**

   The characteristic values of loads are based on statistical data. It is assumed that in ninety-five per cent cases the characteristic loads will not be exceeded during the life of the structures. However, structures are subjected to overloading also. Hence, structures should be designed with loads obtained by multiplying the characteristic loads with suitable factors of safety depending on the nature of loads or their combinations, and the limit state being considered.

   Similarly, the characteristic strength of a material as obtained from the statistical approach is the strength of that material below which not more than five per cent of the test results are expected to fall. However, such characteristic strengths may differ from sample to sample also. Accordingly, the design strength is calculated dividing the characteristic strength further by the partial safety factor for the material and the limit state being considered.

3. **Give four reasons to justify the design of structures by limit state method.**

- Concept of separate partial safety factors of loads of different combinations in the two limit state methods
- Concept of separate partial safety factors of materials depending on their quality control during preparation.
- A structure designed by employing limit state method of collapse and checked for other limit states will ensure the strength and stability requirements at the

collapse under the design loads and also deflection and cracking at the limit state of serviceability. This will help to achieve the structure with acceptable probabilities that the structure will not become unfit for the use for which it is intended.

- The stress block represents in a more realistic manner when the structure is at the collapsing stage (limit state of collapse) subjected to design loads.

4. What are the differences between working stress method (WSM) and limit state method (LSM)?

In **elastic design, i.e. WSM**, the design strength is calculated such that the stress in material is restrained to its yield limit, under which the material follows Hooke's law, and hence the term "elastic" is used. This method yields to uneconomical design of simple beam, or other structural elements where the design governing criteria is stress (static). However, in case of shift of governing criteria to other factors such as fatigue stress, both the methods will give similar design. Also, WSM substantially reduces the calculation efforts.

In **plastic design, i.e. LSM**, as the name suggests, the stress in material is allowed to go beyond the yield limit and enter into the plastic zone to reach ultimate strength. Hence the "moment-rotation" capacity of beam, for example, is utilized making the design more economical. However, due to the utilization of the non-linear zone this method involves arduous calculation.

All other differences are mostly derived from the above stated fundamental difference along with few general differences. Some of these differences are stated below:
1) Serviceability check in case of LSM is required because after the elastic region strain is higher, which results in more deformation, hence a check is necessary.
2) LSM is strain based method whereas WSM is stress based method.
3) LSM is non-deterministic method whereas WSM is deterministic approach.
4) Partial safety factor is used in LSM whereas Safety factor is used in WSM.
5) Characteristic values (derived from probabilistic approach) are used in case of LSM whereas Average or statistic values are used in WSM.

5. What are the assumptions made in working stress method?

- At any cross-section, plane sections before bending remain plain after bending.
- All tensile stresses are taken up by reinforcement and none by concrete, except as otherwise specifically permitted.
- The stress-strain relationship of steel and concrete, under working loads, is a straight line.
- The modular ratio 'm' has the value – $280/3\sigma_{cbc}$; where σ_{cbc} is permissible compressive stress due to bending in concrete in N/mm^2 as specified in Table 21 of IS 456:2000.

6. Explain nature of failure in balanced section, under reinforced section and over reinforced section.

The reinforced concrete section in bending is assumed to fail when the compression strain in concrete reaches the failure strain in bending compression equal to 0.0035. Reinforced concrete beam sections in which the tension steel also reaches yield strain simultaneously as the concrete reaches the failure strain in bending are called **balanced sections.** Reinforced concrete beam sections in which the steel reaches yield strain at loads lower than the load at which the concrete reaches failure strain are called **under-reinforced sections.** Every singly reinforced beam should be designed as under-reinforced sections because this section gives enough warning before failure. Yielding of steel in the section does not mean the structure has failed, as when steel yields, excessive deflection and cracking in beam will occur before failure which gives enough time to occupants to escape before the section fails. The failure in under-reinforced section is due to the concrete reaching its ultimate failure strain of 0.0035 before the steel reaches its failure strain, which is much higher 0.20 to 0.25. Reinforced concrete beam sections, in which the failure strain in concrete is reached earlier than the yield strain of steel is reached, are called **over-reinforced sections.** If such beam is designed and loaded to full capacity then the steel in tension zone will not yield much before the concrete reaches its ultimate strain of 0.0035. This due to little yielding of steel the deflection and cracking of beam does not occur and does not give enough warning prior to failure. Failures in such sections are all of a sudden. This type of design is not recommended in practice of beam design.