

Limit State Method

The limit state method is a method of design of reinforced concrete structures and steel structures. This is one of the most popular methods of designing structures and concepts that are important for the GATE 2023 exam. Designing a structure is based on the material properties of its constituents, and the limit state method of designing considers the ultimate strength of its constituent materials.

For designing structures, material strength is underestimated, and the total load acting over the structure is overestimated to ensure more factor of safety of designing. The limit state method uses the probabilistic approach for calculating the design load and strength of the proposed structure.

Limit State Method Definition

In the limit state method of design, the material's ultimate strength is considered for the design, and the material's safety factor is applied to them. The main objective of the design of structures by this method is to ensure the acceptable probability that that structure will be useable in its overall life span. It can also be said that the strength parameter is always within its limiting value throughout its life span.

Assumptions of Limit State Method

Designing structures is always done with the help of any method, and every method is based on a few facts. The results of any method are based on these facts, called assumptions. In the case of the limit state method of designing, There are some conditions regarding stress-strain relationships, material behaviors, etc. These conditions are known as the assumptions of the limit state method of design. Here assumptions of this method for designing concrete structures are provided:

Assumptions

1. The plain section remains plane before and after bending; these assumptions ensure that the strain diagram is linear.
2. At the time of failure, the maximum strain in concrete at the topmost fiber will be 0.0035
3. The stress-strain curve for the concrete is parabolic up to the strain of 0.002, and stress will be constant up to the strain of 0.0035
4. The tensile strength of concrete below the neutral axis is ignored; it says that the tensile strength of concrete is ignored.
5. Maximum strain in steel at the time of failure should be greater than $f_y/1.15E_s + 0.002$
6. The safety factor for concrete is 1.5, and the partial safety factor for steel is considered 1.15 for designing concrete structures.

Types of Limit State Method

The Limit state design method is based on the probabilistic method, which tells about the probability of the structure withstanding external stresses. It ensures the safety of

structures against collapse and their serviceability condition. Various questions based on this can be seen in the GATE previous year's question paper. Design of structures by limit state method gives a certain probability that the structure will not fail in its design period. Based on IS 456: 2000, the limit state method can be categorized into two types, which are as follows:

Limit State of Collapse

The Limit state of collapse ensures the parameters of structures that prevent failure during its life span. It establishes limits on the parameters like flexural strength, shear strength, torsional strength, etc. The resistance offered by the structure at its critical section should be less than the limiting values of the respected parameters.

Limit State of Serviceability

Limit state of serviceability ensures that the structure remains serviceable throughout its life; it establishes parameters like cracking, deflection, fire resistance, etc. These parameters should be within the permissible limits described in IS 456.

Difference Between Limit State Method and Working Stress Method

The working stress and limit state methods are the methods of designing reinforced concrete and steel structures. In both methods of designing, material strength is underestimated so that design becomes safer, but the estimation of these things is based on different criteria. Here a few differences are provided between these two methods:

Working Stress Method	Limit State Method
The material's yield strength is considered its failure in this design method.	In this design method, the material's ultimate strength is considered its failure.
The working stress method is based on the deterministic approach to designing	The limit state method is based on the probabilistic approach to designing
This method is based on the elastic theory of the material	This method is based on the actual relationship between the stress-strain curve of materials
Permissible stress = Yield stress / FOS	Permissible stress = Ultimate stress / FOS
In this method factor of safety for loads is not used	In this method, partial safety of factor for loads is used
In this method, an exact margin of safety can not be determined	In this method, an exact margin of safety can be determined
This method is a less economical design	This method gives the most economical design of structures.

Advantages of Limit State Method

Various methods for designing concrete structures are available, including the Working stress method, the Limit state method, and the Ultimate load method. These methods are used based on their suitability and other strength parameters. In the earlier era of designing structures, the working stress method was used, but nowadays, the limit state method of design is used for designing concrete structures. The limit state method has many advantages over the other method, which include:

- Designing structures with the limit state method is economical over the working stress method.
- This method considers the material's ultimate strength; hence it utilizes the full strength of the material.
- Cross-sectional dimensions through this design method are lesser than that of the working stress method.
- This method shows how it can bear the load after yielding.

Design of Beams by Limit State Method

Beams are structures that take mainly the transverse load. The design of a beam is based on the parameters like external bending moment, shear force at the critical section, and torsional force (if any), which are widely covered in the GATE CE syllabus. The design of beams can be done by either the working stress method or the limit state method. The beams' dimensions get larger when it is designed by the working stress method, and it becomes an extra safe design but uneconomical. Design of beams by limit state method is economical and provides adequate safety; that's why it is now preferred. Here are the steps of designing beams by limit state method for bending moment, given below:

1. Calculate the maximum external bending moment acting over the beam; It can be determined with the help of a bending moment diagram at the critical section.
2. Calculate the factored bending moment by multiplying the external bending moment with the partial safety factor
3. Assume a section dimension and concrete ingredients like the grade of steel and characteristic strength of concrete.
4. Calculate the area of steel required based on the concrete ingredients and section dimensions.
5. Check that moment of resistance of the beam is more than the factored bending moment; if not, repeat the designing process from step 3.

Design of Steel Structures by Limit State Method

Steel is a metal having high strength in bending and shear. Steel structures are designed to take a higher amount of load. It is suitable in many cases for the designing of concrete structures. Steel structures are preferred in the case of tensile load, but they can also be used for compressive loads because they provide a low-weight structure and a more pliable design.

Steel structures can also be designed by the working stress and the limit state methods. But it is mostly preferred by the limit state method as it provides an

economical design. The designing process of steel structures by this method is given in IS 800. Designing steel structures has been done for the axial load criteria and shear strength criteria.

