

6.2 Limit state design of beams


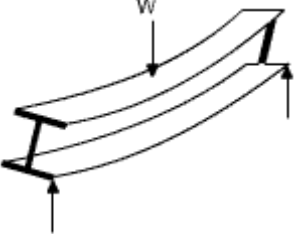
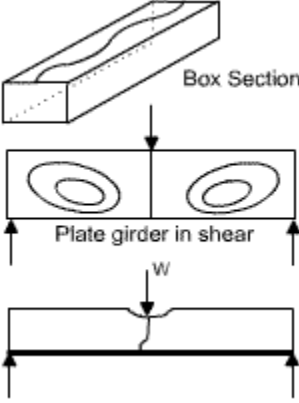
In the working stress or allowable stress method of design, the emphasis is on limiting a particular stress in a component to a fraction of the specified strength of the material of the component. The magnitude of the factor for a structural action depends upon the degree of safety required. Further, elastic behaviour of the material is assumed. The main objection to the permissible stress method is that the stress safety factor relating the permissible stress to the strength of the material is not usually the same as the ratio of the strength to the design load. Thus it does not give the degree of safety based on collapse load.

In the limit state method, both collapse condition and serviceability condition are considered. In this method, the structure has to be designed to withstand safely all loads and deformations likely to occur on it throughout its life. Designs should ensure that the structure does not become unfit for the use for which it is required. The state at which the unfitness occurs is called a limit state. Special features of limit state design method are:

- It is possible to take into account a number of limit states depending upon the particular instance
- This method is more general in comparison to the working stress method. In this method, different safety factors can be applied to different limit states, which is more rational than applying one common factor (load factor) as in the plastic design method.
- This concept of design is appropriate for the design of structures since any new knowledge of the structural behaviour, loading and materials can be readily incorporated.

The limit state design method is essentially based on the concept of probability. Its basic feature is to consider the possibility and probability of the collapse load. In this respect, it is necessary to consider the possibility of reduced strength and increased load.

Table 6.1 Main failure modes of hot-rolled beams

Category	Mode		Comments
1	Excessive bending triggering collapse		This is the basic failure mode provided (1) the beam is prevented from buckling laterally, (2) the component elements are at least compact, so that they do not buckle locally. Such “stocky” beams will collapse by plastic hinge formation.
2	Lateral torsional buckling of long beams which are not suitably braced in the lateral direction. (i.e. “unrestrained” beams)		Failure occurs by a combination of lateral deflection and twist. The proportions of the beam, support conditions and the way the load is applied are all factors, which affect failure by lateral torsional buckling.
3	Failure by local buckling of a flange in compression or web due to shear or web under compression due to concentrated loads		<p>Unlikely for hot rolled sections, which are generally stocky. Fabricated box sections may require flange stiffening to prevent premature collapse.</p> <p>Web stiffening may be required for plate girders to prevent shear buckling.</p> <p>Load bearing stiffeners are sometimes needed under point loads to resist web buckling.</p>

4	<p>Local failure by</p> <p>(1) shear yield of web (2) local crushing of web (3) buckling of thin flanges.</p>		<p>Shear yield can only occur in very short spans and suitable web stiffeners will have to be designed.</p> <p>Local crushing is possible when concentrated loads act on unstiffened thin webs. Suitable stiffeners can be designed.</p> <p>This is a problem only when very wide flanges are employed. Welding of additional flange plates will reduce the plate b / t ratio and thus flange buckling failure can be avoided.</p>
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The object of design is to keep an acceptable level the probability of any limit state not being exceeded. This is achieved by taking account of the variation in strength and properties of materials to be used and the variations in the loads to be supported by the structure, by using the characteristic values of the strength of materials as well as the loads to be applied. The deviations from the characteristic values in the actual structures are allowed by using their design values. The characteristic values should be based on statistical evidence where necessary data are available; where such data are not available they should be based on an appraisal of experience. The design values are derived from the characteristic values through the use of partial safety factors, one for material strengths and the other for loads and load effects.