LIMIT STATE DESIGN

During recent decades, the emphasis in structural design has been moving from permissible stress design to limit state design since the latter approach makes possible rigorously designed, yet economical, structures by considering relevant modes of failure directly.

INTRODUCTION

The structural designer is to design a building or structure that is safe, reliable, functional and economical to build and maintain.

Building codes set out design loads and contain rules governing the ways in which these are to be applied, often by way of reference to design standards.

In earlier times, structures were built using intuition, trial and error, and the rules of proportion acquired through experience. This led eventually to (increasingly sophisticated) design by calculations based on assessment of successful buildings, experimental work and mathematical modelling of the behaviour of materials and structural systems.

Significant changes have taken place in design standards over the years. For example:

- Analysis based on member strength rather than sectional stress alone was introduced.
- Requirements were established to provide adequate safety for anchorage against wind uplift and for stability against overturning.
- As structures became lighter, new serviceability requirements for deflection, cracking and vibration were introduced.

Initially, design was based on limiting stresses within members in structures to permissible stresses. This involved the concept of a factor of safety, the numerical value by which the load that would cause failure of the structure or element was divided, to give the maximum permissible working load on the structure or element.

Gradually, as our understanding of loading and material behaviour deepened and our calculation capacity (due to computers) increased, permissible stress design was replaced by methods based on assessing acceptable behaviour in the context of failure criteria, or limit states. These seek to ensure that the probability of failure is reliably predictable and acceptably low.

LIMIT STATE DESIGN (LSD)

All structures have two basic requirements in common: safety from collapse and satisfactory performance for intended use (serviceability).

LSD considers how a structure may fail to satisfy these basic requirements (i.e. no longer perform its intended functions). The LSD process considers two sets of conditions or states:

Ultimate limit state (ULS) – This relates to the safety of the structure and corresponds to strength and stability. It defines the limits for total or partial collapse. The effect of exceeding the ULS is always irreversible and the first time this occurs will cause failure. For ULS the design loads are increased by a load factor.

Serviceability limit state (SLS) – This represents conditions adversely affecting the expected performance of the structure under service loads. SLS relates to satisfactory performance and corresponds to maximum acceptable deflections, vibrations and local deformations. When permanent local damage or permanent unacceptable deformations occur, the SLS is exceeded irreversibly, and the first time this occurs is deemed to cause non-compliance or collapse.

Appendix C of AS/NZS 1170.0 provides guidance on SLS.

To unify future structural codes and standards and to minimise their number and size, the following principles are being adopted (by Standards organisations):

- The actions, load factors and main serviceability requirements depend only on the ***use*** of the structure and will therefore be given in the structural design actions standards. (e.g. AS/NZS 1170 parts 0 to 4)
- The resistances, resistance factors and structural theory depend only on the ***material and type of structure*** and will therefore be contained in the material design standards. (e.g. AS 3600 for concrete, AS 4100 for steel, AS 1288 for glass, AS/NZS 1664 for aluminium and AS 1684.1, AS 1684.2, AS 1684.3, and AS 1684.4 for timber)

The limit states provide an invaluable checklist of the structural requirements for which design calculations may be required.

Limit state design, while providing consistent safety and serviceability, aims to ensure an economical use of materials. It provides a basic calculation tool for both designing and evaluating structures, and for unifying structural codes and standards.

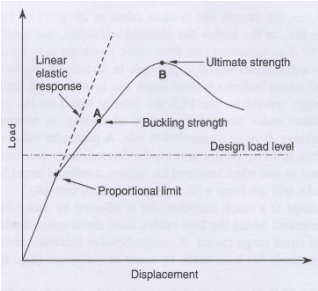
Definitions

Limit State – A state beyond which the structure no longer satisfies the design performance requirements.

Ultimate Limit State (ULS) – A state associated with collapse or other forms of failure.

Serviceability Limit State (SLS) – A state which corresponds to the conditions beyond which specified service requirements for a structure or a structural element are no longer met.

Permissible Stress Design (PSD) – Design in which the calculated (structural member) stresses do not exceed permissible values that are based on the elastic limit of the material.



This figure shows point A representing the upper limit for PSD, and B representing the ultimate strength limit state beyond which failure by collapse occurs.

Design requirements should be satisfied by all elements and the entire structure.
(Eureka Tower, Melbourne)

Relevant standards

AS/NZS 1170 (series) *Structural design actions*
Part 0 *General principles*
Part 1 *Permanent, imposed and other actions*
Part 2 *Wind actions*
Part 3 *Snow and ice actions*
Part 4 *Earthquake actions in Australia*
AS 5104 *General principles on reliability for structures.*