AUSTRALIAN STEEL INSTITUTE

AS 4100 DS01

Steel Structures – Introduction to limit states design

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AS 4100 STEEL STRUCTURES

Introduction

This is the first of a series of Technical Data Sheets to assist designers in the use of AS 4100. This Technical Data Sheet gives a brief introduction to limit states design, and a preliminary description of the elastic analysis methods in AS 4100.

Following Technical Data Sheets elaborate in greater detail on these and other issues such as second-order effects.

Definition of a limit state

When a structure or part of a structure is rendered unfit for use it reaches a 'limit state'. In this state it ceases to perform one of the functions or to satisfy the conditions for which it was designed. Relevant limit states for steel structures include strength, serviceability, stability, fatigue, brittle fracture, fire, and earthquake.

Australian Standard AS 4100, *Steel structures*, introduces a limit states approach to steel design which is based on statistical models of load and material strength distributions.

Limit states design requires structural members and connections to be proportioned such that the **design capacity** (ϕR_u) is not less than *the* ***design action effect*** (S^*) resulting from the **design load** (W^*_1), i.e. –

$$S^* \leq \phi R_u$$

The **design action or design load** (W^*_1) is the combination of the nominal actions or loads imposed upon the structure, multiplied by the appropriate load factors, as specified in AS 1170.1, AS 1170.2 or AS 1170.3. The **design action or loads** are identified by a superscript (*) after the appropriate action or load.

The **design action effects (S^*)** are the actions (e.g. design bending moments, shear forces, axial loads, etc.) computed from the **design actions** or **design loads** using an acceptable method of analysis. These effects are identified by a superscript (*) after the appropriate action effect, for example M^* describes the design bending moment.

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The **design capacity** (ϕR_u) is the product of the nominal capacity (R_u) and the appropriate capacity factor (ϕ) given in Table 3.4 of AS 4100. R_u is determined from Sections 5 to 9 of AS 4100, as appropriate.

For example, when considering the strength limit state design of beams with full lateral restraint, the nominal member moment capacity (M_b) is equal to the nominal section moment capacity (M_s) where—

$$M_s = f_y Z_e$$

and

f_y = yield stress used in design
Z_e = effective section modulus

Note: The values of f_y and Z_e are given in the AISC and BHP Tables.

In this case, the design capacity (ϕR_u) is the design section moment capacity (ϕM_s) so that—

$$\phi R_u = \phi M_s = \phi f_y Z_e$$

The design action effect (S^*) is the design bending moment (M^*) which must satisfy—

$$M^* \leq \phi M_s$$

First-order elastic analysis

This method of structural analysis is a means of determining the design bending moments, shear forces, axial forces (i.e. design action effects) and design deflections of a structure subjected to relevant imposed design loads. In a first-order elastic analysis, second-order effects caused by changes in the geometry of the member are not accounted for in the analysis. It is assumed that the member remains elastic under the action of the design loads for all limit states. This method is the common method of analysis used in design.

Second-order elastic analysis. This method of structural analysis has the same function as first-order elastic analysis. However, it accounts for the effects of the design loads acting on the structure and its members in their displaced and deformed configuration.

Second-order effects. Not all structures have second-order effects. When second-order effects occur, they are accounted for by using either—

(a) a first-order elastic analysis with moment amplification factors as determined in accordance with Section 4 of AS 4100. Note that this method is limited to amplification factors that are not greater than 1.4 (i.e. second-order effects are less than or equal to 40%), which is the case for most steel structures; or

(b) a second-order elastic analysis determined in accordance with Appendix E of AS 4100