chapter 1

Introduction

1.1 Developments in steel structures

Early steel structures in bridges, industrial buildings, sports stadia and exhibition buildings were fully exposed. At the time no special consideration had been given to aesthetics. The form of a structure was driven by its function. Riveted connections had a certain appeal without any further treatment. As the use of steel spread into commercial, institutional and residential buildings with their traditional masonry facades, the steel structure as such was no longer a principal modelling element and became utilitarian, merely a framework of beams and columns.

The role of steel started to change with the trend towards lighter envelopes, larger spans, and the growing number of sports and civic facilities in which structural steel had an undisputed advantage. Outstanding lightweight structures have been constructed in the past four decades. Structural framing exposed to full view has taken many forms, including space frames, barrel vaults, cable stayed and cable net roofs. The trend continues unabated with increasing boldness and innovation by designers.

The high visibility of structural framing has brought about a need for more aesthetically pleasing connections, where the architect might outline a family of connection types. In this instance, standardisation on a project-to-project basis is preferred to universally applied standard connections. Structural designers and drafters have been under pressure to re-examine their connection design. Pin joints often replace bolted connections, simply to avoid association with industrial-type joints. Increasingly, 3D computer modelling and scale models are used for better visualisation. Well-designed connections need not be more expensive because fabrication tools have become more versatile. Even so, it is necessary to keep costs down through simplicity of detailing and the maximum possible repetition.

In many other situations, structural steelwork is also used in ‘non-visible’ (e.g. behind finishes), industrial and resource applications. In these instances general standardisation of connections across all projects is worthwhile. This makes structural framing more attractive in terms of costs, reduced fabrication and erection effort, without any reduction in quality and engineering efficiency.

Therefore, constructing in steel provides the designer with a panoply of solutions from which to innovate. In Australia and throughout the world there are fine examples of structural steel being used in many outstanding commercial buildings as well as in reticulated domes and barrel vaults, space truss roofs, cable nets and other lightweight structures. A way for the designer to partake in this exciting development is to visit a good library of architecture and engineering technology or to contact resource centres within the relevant industry associations (e.g. Australian Steel Institute, HERA in New Zealand).

To be successful in the current creative environment, structural steel designers need to shed many of the old precepts and acquire new skills. One essential element is a basic understanding of the behaviour of structural steel and the use of a design or modelling methodology that adequately reflects this behaviour while emphasising efficiency and economy. Such a methodology is embodied in the limit states design philosophy incorporated in key design Standards, such as AS 4100 (Steel Structures) and NZS 3404 (Steel Structures Standard). The mastery of such methods is an ongoing task, which constantly expands as one delves deeper into the subject.

1.2 Engineering design process

The structural engineer's ('designer') involvement with a project starts with the design brief, setting out the basic project criteria. The designer's core task is to conceive the structure in accordance with the design brief, relevant Standards, statutory requirements and other constraints. Finally, the designer must verify that the structure will perform adequately during its design life.

It has been said that the purpose of structural design is to build a building or a bridge. In this context the designer will inevitably become involved in the project management of the overall design and construction process. From a structural engineering perspective, the overall design and construction process can be categorised sequentially as follows.

(a) Investigation phase:
- site inspection
- geotechnical investigation
- study of functional layout
- research of requirements of the statutory authorities
- determination of loads arising from building function and environment
- study of similar building designs.

(b) Conceptual design phase:
- generation of structural form and layout
- selecting materials of construction
- constructability studies
- budget costing of the structural options
- evaluation of options and final selection.

(c) Preliminary design phase:
- estimation of design actions and combinations of actions

- identification of all solution constraints
- generation of several framing systems
- preliminary analysis of structural framework
- preliminary sizing of members and connections
- preliminary cost estimate
- quality assessment of the design solution
- client's review of the preliminary design
- reworking of the design in line with the review.

(d) Final design phase:
- refining the load estimates
- final structural analysis
- determination of member types and sizes
- detail design of connections
- study of the sequence of construction
- quality review of the final design (QA)
- cost estimate
- client's review of the design and costing
- modification of the design to meet client's requirements.

(e) Documentation phase:
- preparation of drawings for tendering
- writing the specifications
- preparing bills of quantities
- final structural cost estimate
- preparing a technical description of the structure
- quality review of the tender documentation (QA)
- client's approval of the tender documentation
- calling tenders.

(f) Tendering phase:
- preparing the construction issue of drawings
- assisting the client with queries during tendering
- assisting in tender evaluation and award of contract.

(g) Construction phase, when included in the design commission (optional):
- approval of contractor's shop drawings
- carrying out periodical inspections
- reviewing/issuing of test certificates and inspection
- final inspection and certification of the structure
- final report.

The process of development and selection of the structural framing scheme can be assisted by studying solutions and cost data of similar existing structures. To arrive at new and imaginative solutions, the designer will often study other existing building structures and then generate new solutions for the particular project being designed.

Much has been written on design philosophy, innovation and project management, and readers should consult the literature on the subject. This Handbook's main emphasis is on determination of action (i.e. load) effects and the design of frames, members and connection details for low-rise steel structures. The theory of structural mechanics does not form part of the Handbook's scope and the reader should consult other texts on the topic.

1.3 Standards and codes of practice

The designer has only limited freedom in determining nominal imposed loads, setting load factors and serviceability limits. This information is normally sourced from the appropriate statutory or regulatory authority e.g. Building Code of Australia (BCA [2003]), which is gazetted into State legislation and may in turn refer to relevant 'deemed to comply' Standards (AS 4100 etc.).

Design Standards have a regulatory aspect, and set down the minimum criteria of structural adequacy. This can be viewed as the public safety aspect of the Standards. Additionally, Standards provide acceptable methods of determining actions (e.g. forces), methods of carrying out structural analyses, and sizing of members and connections. This gives the design community a means of achieving uniformity and the ability to carry out effective quality-assurance procedures. Standards also cover the materials and workmanship requirements of the structure (quality, testing and tolerances), which also impact on the design provisions. The degree of safety required is a matter of statutory policy of the relevant building authorities and is closely related to public attitudes about the risk of failure.

A list of some of the relevant Standards and their 'fitness' aspects is given in Table 1.1.

Table 1.1 List of relevant steelwork Standards

Standard	Fitness aspect—design
(a) AS Loading Standards	
AS 1170, Part 1	Dead and live loads and load combinations
AS 1170, Part 2	Wind loads
AS 1170, Part 3	Snow loads
AS 1170, Part 4	Earthquake loads
(b) AS/NZS structural design actions intended to replace AS 1170 referred to in:	
AS/NZS 1170, Part 0	General principles
AS/NZS 1170, Part 1	Permanent, imposed and other actions
AS/NZS 1170, Part 2	Wind actions
AS/NZS 1170, Part 3	Snow loads
(c) Other standards:	
AS 2327	Composite construction
AS 4100	Steel Structures. Includes resistance factors, materials, methods of analysis, strength of members and connections, deflection control, fatigue, durability, fire resistance.
AS/NZS 4600	Cold-formed steel structures

Note: At the time of writing this handbook, both the (a) AS 1170 and (b) AS/NZS 1170 series of 'loading' Standards are referred to in the Building Code of Australia (BCA [2003]–January 2003 amendment).

continued

Table 1.1 List of relevant steelwork Standards (continued)

Standard	Fitness aspect—design/material quality
AS 1111	ISO metric hexagon bolts (Commercial bolts)
AS 1163	Structural steel hollow sections
AS/NZS 1252	High-strength bolts, nuts and washers
AS/NZS 1554, Parts 1–5	Welding code
AS/NZS 3678	Hot-rolled plates
AS/NZS 3679, Part 1	Hot-rolled bars and sections
AS/NZS 3679, Part 2	Welded I sections

A more exhaustive listing of Australian and other standards of direct interest to the steel designer is given in Appendix A.

This edition of the Handbook is generally intended to be used with AS 4100:1998 Steel Structures, which is in limit states format. Commentary is also given on related loading/action Standards.

1.4 General structural design principles

For the purposes of this text, the term 'structure' includes structural members, connections, fasteners and frames that act together in resisting imposed actions (loads, pressures, displacements, strains, etc.). The essential objective of structural design is to define a structure capable of remaining fit for the intended use throughout its design life without the need for costly maintenance. To be fit for its intended use the structure must remain stable, safe and serviceable under all actions and/or combinations of actions that can reasonably be expected during its service life, or more precisely its *intended* design life.

Often the use or function of a structure will change. When this occurs it is the duty of the owner of the building to arrange for the structure to be checked for adequacy under the new imposed actions and/or structural alterations.

Besides the essential objectives of adequate strength and stability, the designer must consider the various requirements of adequacy in the design of the structure. Of particular importance is serviceability: that is, its ability to fulfil the function for which that structure was intended. These additional criteria of adequacy include deflection limits, sway limits as well as vibration criteria.

1.5 Limit states design method

The 'limit state of a structure' is a term that describes the state of a loaded structure on the verge of becoming unfit for use. This may occur as a result of failure of one or more members, overturning instability, excessive deformations, or the structure in any way ceasing to fulfil the purpose for which it was intended. In practice it is rarely possible to determine the exact point at which a limit state would occur. In a research laboratory the chance of determining the limit state would be very good. The designer can deal only