Design of Cold-formed Steel Structures

Eurocode 3: Design of Steel Structures
Part 1-3: Design of Cold-formed Steel Structures

Dan Dubina
Viorel Ungureanu
Raffaele Landolfo

ECCS
CECM
EKS

WILEY-BLACKWELL

Ernst & Sohn
A Wiley Company

ECCS Eurocode Design Manuals

DESIGN OF COLD-FORMED STEEL STRUCTURES

ECCS EUROCODE DESIGN MANUALS

DESIGN OF STEEL STRUCTURES
Luís Simões da Silva, Rui Simões and Helena Gervásio

FIRE DESIGN OF STEEL STRUCTURES
Jean-Marc Franssen and Paulo Vila Real

DESIGN OF PLATED STRUCTURES
Darko Beg, Ulrike Kuhlmann, Laurence Davaine and Benjamin Braun

FATIGUE DESIGN OF STEEL AND COMPOSITE STRUCTURES
Alain Nussbaumer, Luís Borges and Laurence Davaine

Design of Cold-formed Steel Structures
Dan Dubina, Viorel Ungureanu and Raffaele Landolfo

AVAILABLE SOON

DESIGN OF COMPOSITE STRUCTURES
Markus Feldman and Benno Hoffmeister

DESIGN OF JOINTS IN STEEL AND COMPOSITE STRUCTURES
Jean-Pierre Jaspart, Klaus Weynand

INFORMATION AND ORDERING DETAILS

For price, availability, and ordering visit our website **www.steelconstruct.com**.
For more information about books and journals visit **www.ernst-und-sohn.de**

DESIGN OF COLD-FORMED STEEL STRUCTURES

Eurocode 3: Design of Steel Structures
Part 1-3 – Design of Cold-formed Steel Structures

Dan Dubina
Viorel Ungureanu
Raffaele Landolfo

ECCS CECM EKS

WILEY-BLACKWELL

Ernst & Sohn
A Wiley Company

Design of Cold-formed Steel Structures

1st Edition, 2012

Published by:
ECCS – European Convention for Constructional Steelwork
publications@steelconstruct.com
www.steelconstruct.com

Sales:
Wilhelm Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin

ISBN (ECCS): 978-92-9147-107-2
ISBN (Ernst & Sohn): 978-3-433-02979-4
Legal dep.: 348490/12 - Printed in Multicomp Lda, Mem Martins, Portugal
Photo cover credits: BRITT Ltd., Timisoara, Romania.

TABLE OF CONTENTS

Chapter 7

FOREWORD

Following pioneering research in the 1940s, research into cold-formed steel intensified in the 1970s and led to numerous national European design specifications, and subsequently the preparation of Part 1-3 of Eurocode3 (EN1993-1-3) for cold-formed steel structures. Now a Euronorm, EN1993-1-3 is fully embedded in the Eurocode framework.

This book serves as a reference text for design engineers using EN1993-1-3. It forms part of the suite of ECCS Eurocode Design Manuals prepared in recent years for other parts of EN1993 and other Eurocodes to aid the implementation of Eurocodes in European states. The book draws on the authors' considerable experience with designing cold-formed steel structures, both as academics and practitioners, and strikes a balance between theory and practice.

Applications of cold-formed steel have broadened over the years. Cold-formed steel is now used as primary structural elements, as in steel framed residential buildings, steel storage racks, portal frames, and tubular truss and frame structures, and as secondary structural elements, as in roofing and wall systems featuring purlins, girts and corrugated steel sheeting. Additionally, integrated building systems have been developed, such as cassettes, as have stressed skin principles for designing the building envelope.

The design of cold-formed steel is perceived to be challenging by many structural engineers because the thinness of the steel leads to buckling and failure modes not found in the design of hot-rolled and fabricated steel structures. Furthermore, roll-forming techniques have developed rapidly in recent decades and spawned highly optimised cross sections featuring intermediate stiffeners and complex lip stiffeners, which are not easily designed using conventional methods. The book covers the design of structural members of complex shapes and connections as well as the design of integrated structural solutions, such as cassettes, and design using stressed skin principles. The structural behaviour and design to EN1993-1-3 are explained and numerous worked examples are included to guide or enable a cross-check for structural design engineers.

The final Chapter 8 deserves a special mention as it addresses the comprehensive range of considerations other than structural to be made in cold-formed steel construction, including thermal transmission and sound, serviceability, durability, sustainability and recyclability. Methods of design for single and multi-storey housing are explained in detail, concluding with a comprehensive worked example of a residential building.

This book presents a landmark in the development of guidelines for the structural design of cold-formed steel. It is arguably the most extensive reference available for designing cold-formed steel structures to EN1993-1-3, and will serve the structural engineering community well in adapting to the expanding range of residential and industrial applications of cold-formed steel.

Kim Rasmussen
Chairman, Centre for Advanced Structural Engineering, University of Sydney

PREFACE

The use of cold-formed steel members in building construction began in the 1850s in both the United States and Great Britain. In the 1920s and 1930s, acceptance of cold-formed steel as a construction material was still limited because there was no adequate design standard and there was limited information on material use in building codes. One of the first documented uses of cold-formed steel as a building material is the Virginia Baptist Hospital, constructed around 1925 in Lynchburg, Virginia, USA. The building structure was composed by masonry and the floors supported by cold-formed steel built-up joists of back- to- back lipped channel sections. Only some 20 years later, only, Lustron Corporation built in Albany, New York, with almost 2500 steel-framed homes, with the framing, finishes, cabinets and furniture made from cold-formed steel. These inexpensive houses were built for the veterans returning from the World War II. This was the beginning of *cold-formed steel adventure* in building.

In recent years, cold formed steel sections are used more and more as primary framing components. Wall stud systems in housing, trusses, building frames or pallet rack structures are some examples. As secondary structural systems they are used as purlins and side rails or floor joists, as well as in building envelops. Cassette sections in modern housing systems play simultaneously the role of primary structure and envelope. Profiled decking is widely used as basic components in composite steel-concrete slabs.

Cold-formed steel members are efficient in terms of both their stiffness and strength. Additionally, because the base steel is thin, even less than 1mm thick when high strength steel is used, the members are lightweight. The use of thinner sections and high strength steel leads to design problems for structural engineers which may not normally be encountered in routine structural steel design. Further, the shapes which can be cold-formed are often considerably more complex than hot-rolled steel shapes such as I-sections and plain channel sections. The cold-formed sections commonly have mono-symmetric or point symmetric shapes, and normally have stiffening lips on flanges and intermediate stiffeners in wide flanges and webs. Both simple and complex shapes can be formed for structural and non-structural applications.

Cold-formed steel design is dominated by two specific problems, i.e. (1) *stability behaviour*, which is dominant for design criteria of thin sections, and (2) *connecting technology*, which is specific and influences significantly the structural performance and design detailing.

Special design standards have been developed to cover the specific problems of cold-formed steel structures. In the USA, the Specification for the design of cold-formed steel structural members of the American Iron and Steel Institute was first produced in 1946 and has been regularly updated based on research to the most recent 2007 edition, AISI S100-07, entitled *North American Specification for Design of Cold-Formed Steel Structural Members.*

In Europe, the ECCS Committee TC7 originally produced the European Recommendations for the design of light gauge steel members in 1987 (ECCS, 1987). This European document has been further developed and published in 2006 as the European Standard Eurocode 3: *Design of steel structures. Part 1-3: General Rules. Supplementary rules for cold-formed thin gauge members and sheeting* (EN 1993-1-3, 2006).

In Australia and New Zeeland, the last version of specification for the design of cold-formed steel structures, AS/NZS 4600, was published in December 2005, and the review of cold-formed steel design specification could be continued around the world.

The market share of cold-formed structural steelwork continues to increase in the developed world. The main reasons can be found in the improving technology of manufacture and corrosion protection which leads, in turn, to an increased competitiveness of resulting products as well as new applications. Recent studies have shown that the coating loss for galvanised steel members is sufficiently slow, and indeed slows down to effectively zero, than a design life in excess of 60 years can be guaranteed.

The range of use of cold-formed steel sections specifically as load-bearing structural components is very wide. Besides building applications, cold-formed steel elements can be met in the Automotive industry, Shipbuilding, Rail transport, in Aircraft industry, Highway engineering, Agricultural and Industry equipment, Office equipment, Chemical, Mining, Petroleum, Nuclear and Space industries.

This book is primarily concerned with the design of cold-formed steel members and structures in building construction in Europe. For this reason it is mainly focused on the EN 1993-1-3, and the related parts of EN 1993 (e.g. EN 1993-1-1, EN 1993-1-5, EN 1993-1-8, etc.).

Generally, the book contains the theoretical background and design rules for cold-formed members and connections, accompanied by design oriented flow charts and worked examples for common building application.

The book was conceived primarily as a technical support for structural engineers in design and consulting offices, but it is expected to be of interest and useful for students and staff members of structural engineering faculties, as well as, for engineers working in steelwork industry.

Dan Dubina
Viorel Ungureanu
Raffaele Landolfo

Chapter 1

INTRODUCTION TO COLD-FORMED STEEL DESIGN

1.1 GENERAL

Cold-formed steel products are found in all aspects of modern life. The use of these products are multiple and varied, ranging from “tin” cans to structural piling, from keyboard switches to mainframe building members. Nowadays, a multiplicity of widely different products, with a tremendous diversity of shapes, sizes, and applications are produced in steel using the cold-forming process.

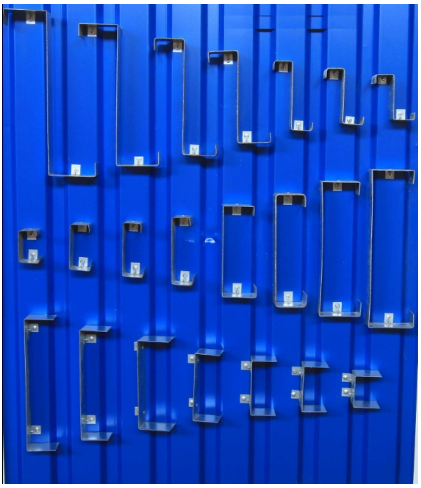
The use of cold-formed steel members in building construction began about the 1850s in both the United States and Great Britain. However, such steel members were not widely used in buildings until 1940.

In recent years, it has been recognised that cold-formed steel sections can be used effectively as primary framing components. In what concerns cold-formed steel sections, after their primarily applications as purlins or side rails, the second major application in construction is in the building envelope. Options for steel cladding panels range from inexpensive profiled sheeting for industrial applications, through architectural flat panels used to achieve a prestigious look of the building. Light steel systems are widely used to support curtain wall panels. Cold-formed steel in the form of profiled decking has gained widespread acceptance over the past fifteen years as a basic component, along with concrete, in composite slabs. These are now prevalent in the multi-storey steel framed building market. Cold-formed steel members are efficient in terms of both stiffness and strength. In addition, because the steel may be even less than 1 mm thick, the members are light weight. The already impressive load carrying capabilities of cold-formed steel members will be enhanced by current work to develop composite systems, both for wall and floor structures.

The use of cold-formed steel structures is increasing throughout the world with the production of more economic steel coils particularly in coated form with zinc or aluminium/zinc coatings. These coils are subsequently formed into thin-walled sections by the cold-forming process. They are commonly called "Light gauge sections" since their thickness has been normally less than 3 mm. However, more recent developments have allowed sections up to 25 mm to be cold-formed, and open sections up to approximately 8 mm thick are becoming common in building construction. The steel used for these sections may have a yield stress ranging from 250 MPa to 550 MPa (Hancock, 1997). The higher yield stress steels are also becoming more common as steel manufacturers produce high strength steel more efficiently.

The use of thinner sections and high strength steels leads to design problems for structural engineers which may not normally be encountered in routine structural steel design. Structural instability of sections is most likely to occur as a result of the thickness of the sections, leading to reduced buckling loads (and stresses), and the use of higher strength steel typically makes the buckling stress and yield stress of the thin-walled sections approximately equal. Further, the shapes which can be cold-formed are often considerably more complex than hot-rolled steel shapes such as I-sections and unlipped channel sections. Cold-formed sections commonly have mono-symmetric or point-symmetric shapes, and normally have stiffening lips on flanges and intermediate stiffeners in wide flanges and webs. Both simple and complex shapes can be formed for structural and non-structural applications as shown in Figure 1.1. Special design standards have been developed for these sections.

In the USA, the Specification for the design of cold-formed steel structural members of the American Iron and Steel Institute was first produced in 1946 and has been regularly updated based on research to the most recent 2007 edition (AISI, 1996, 1999, 2001, 2004, 2007). The first edition of the unified *North American Specification* (AISI, 2001) was prepared and issued in 2001, followed by *Supplement 2004: Appendix 1,* *Design of Cold-Formed Steel Structural Members Using Direct Strength Method* (AISI, 2004). It is applicable to the United States, Canada and Mexico for the design of cold-formed steel structural members. In 2007, the second edition of the *North American Specification for the Design of Cold-Formed Steel Structural Members* was issued (AISI, 2007). The document was prepared on the basis of the 2001 edition of the Specification, the Supplement 2004 to the 2001 Specification, and subsequent developments. The new and revised provisions provide up-to-date information for the design of cold-formed steel structural members, connections, assemblies, and systems.

a) 

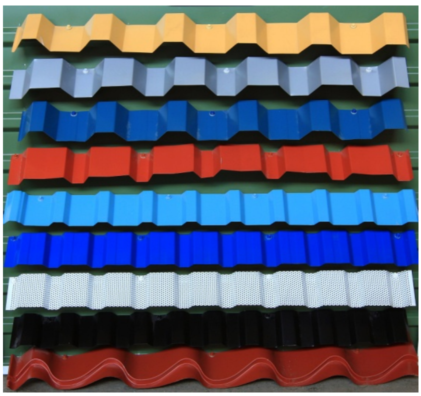
b) 

Figure 1.1 – Collection of cold-formed steel sections shapes:
a) sections for cold-formed steel structural members; b) profiled sheets

In Europe, the ECCS Committee TC7 originally produced the European Recommendations for the design of light gauge steel members in 1987 (ECCS, 1987). This European document has been further developed and published in 2006 as the European Standard Eurocode 3: *Design of steel structures. Part 1-3: General Rules. Supplementary rules for cold-formed thin gauge members and sheeting* (CEN, 2006a).

In Australia and New Zeeland, a revised limit states design standard AS/NZS4600 for the design of cold-formed steel structures was published in December 2005 (AS/NZS 4600:2005).

The market share of cold-formed structural steelwork continues to increase in the developed world. The reasons for this include the improving technology of manufacture and corrosion protection which leads, in turn, to the increase competitiveness of resulting products as well as new applications. Recent studies have shown that the coating loss for galvanised steel members is sufficiently slow, and indeed slows down to effectively zero, that a design life in excess of 60 years can be guaranteed.

The range of use of cold-formed steel sections specifically as load-bearing structural components is very wide, encompassing residential, office and industrial buildings, the automobile industry, shipbuilding, rail transport, the aircraft industry, highway engineering, agricultural and industry equipment, office equipment, chemical, mining, petroleum, nuclear and space industries.

This book is primarily concerned with the design of cold-formed steel members and structures in building construction in Europe and for this reason it is based on the European Design Code EN1993-1-3 (CEN, 2006a).

1.2 COLD-FORMED STEEL SECTIONS

1.2.1 Types of cold-formed steel sections

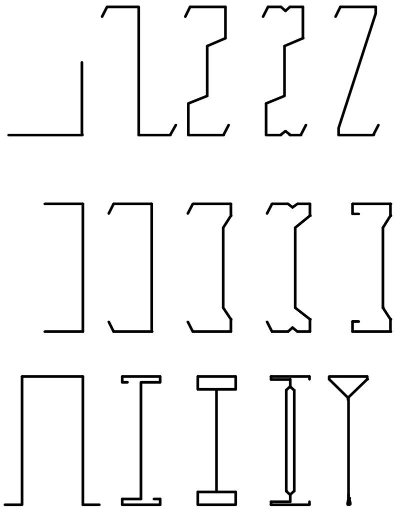
Cold-formed members and profiled sheets are steel products made from coated or uncoated hot-rolled or cold-rolled flat strips or coils. Within the permitted range of tolerances, they have constant or variable cross section.

Cold-formed structural members can be classified into two major types:

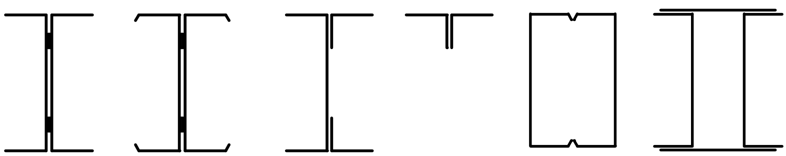
- Individual structural framing members;
- Panels and decks.

Individual structural members (bar members) obtained from so called "long products" include:

- single open sections, shown in Figure 1.2a;
- open built-up sections (Figure 1.2b);
- closed built-up sections (Figure 1.2c).



a) Single open sections



b) Open built-up sections c) Closed built-up sections

Figure 1.2 – Typical forms of sections for cold-formed structural members

Usually, the depth of cold-formed sections for bar members ranges from 50 – 70 mm to 350 – 400 mm, with thickness from about 0.5 mm to 6 mm. Figure 1.3 shows, as an example, some series of lipped channel and "sigma" sections (www.kingspanstructural.com/multibeam/ – Multibeam products).

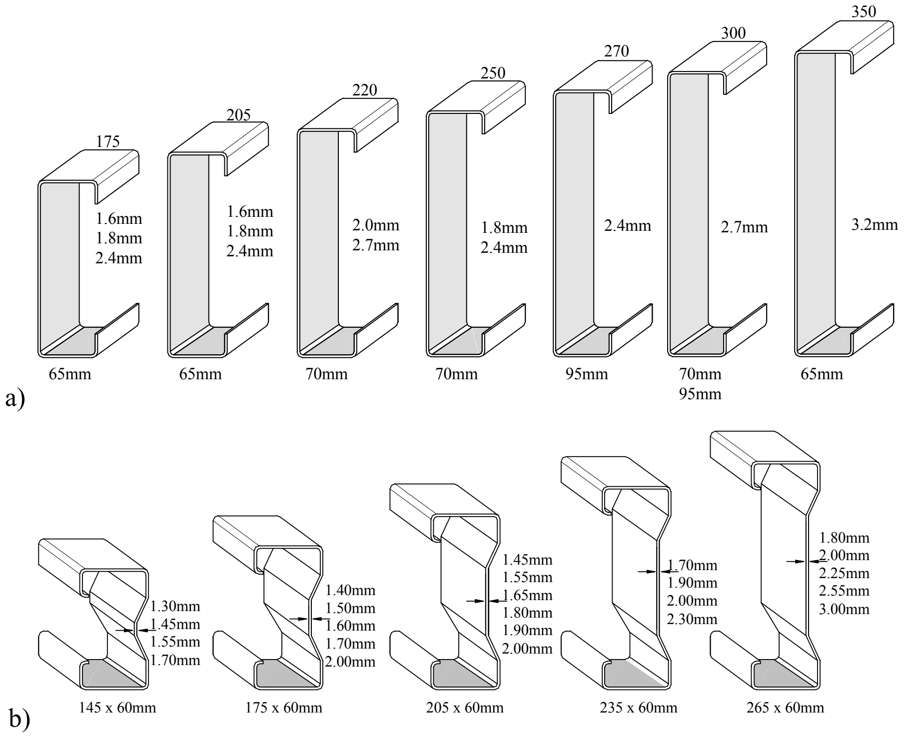


Figure 1.3 – Multibeam sections: a) Lipped Channels; b) Σ sections

Panels and decks are made from profiled sheets and linear trays (cassettes) as shown in Figure 1.4. The depth of panels usually ranges from 20 to 200 mm, while thickness is from 0.4 to 1.5 mm.

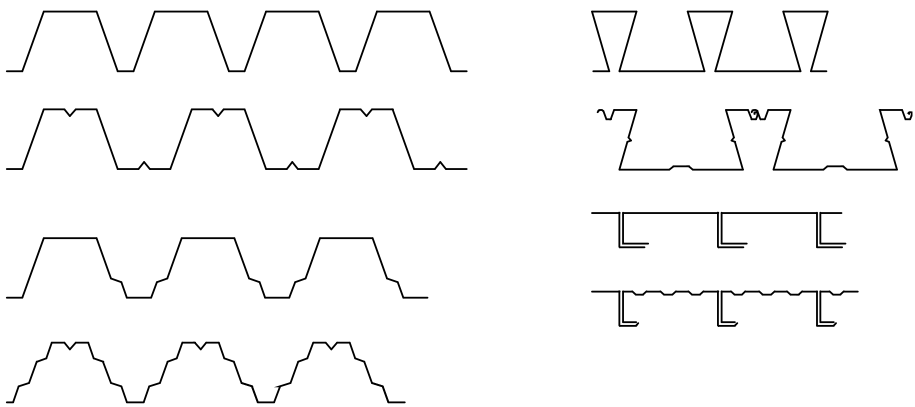
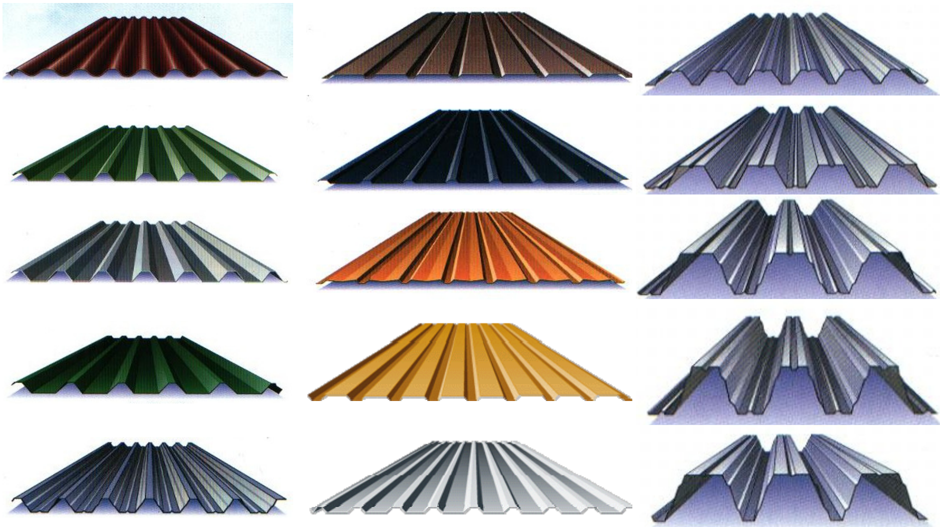


Figure 1.4 – Profiled sheets and linear trays

Figure 1.5 shows examples of Rannila corrugated sheets for roofing, wall cladding systems and load-bearing deck panels.



a) Roofing sheeting (t=0.45-1.0mm) b) Wall cladding sheeting (t=0.45-0.7mm) c) Deck sheeting (t=0.6-1.5mm)

Figure 1.5 – Rannila sheeting products

In order to increase the stiffness of both cold-formed steel sections and sheeting, edge and intermediate stiffeners are used (Figure 1.6); they can be easily identified in examples from Figures 1.3 and 1.5.

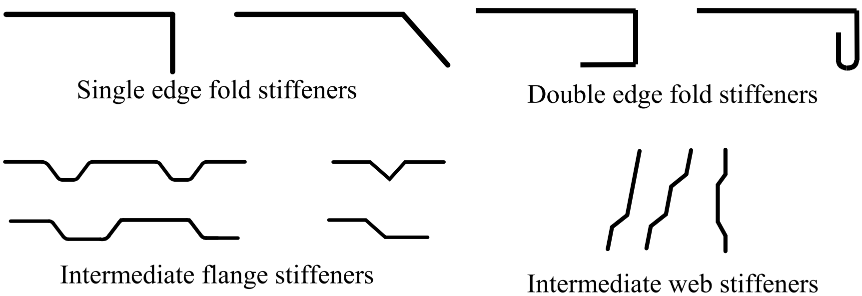


Figure 1.6 – Typical forms of stiffeners for cold-formed members and sheeting

In general, cold-formed steel sections provide the following advantages in building construction (Yu, 2000):

- As compared with thicker hot-rolled shapes, cold-formed steel members can be manufactured for relatively light loads and/or short spans;
- Nestable sections can be produced, allowing for compact packaging and shipping;
- Unusual sectional configurations can be produced economically by cold-forming operations (see Figure 1.1), and consequently favourable strength-to-weight ratios can be obtained;
- Load-carrying panels and decks can provide useful surfaces for floor, roof, and wall construction, and in other cases they can also provide enclosed cells for electrical and other conduits;
- Load-carrying panels and decks not only withstand loads normal to their surfaces, but they can also act as shear diaphragms to resist force in their own planes if they are adequately interconnected to each other and to supporting members.

Compared with other materials such timber and concrete, the following qualities can be realised for cold-formed steel structural members.

- Lightness;
- High strength and stiffness;
- Ability to provide long spans, up to 12 m (Rhodes, 1991);
- Ease of prefabrication and mass production;
- Fast and easy erection and installation;
- Substantial elimination of delays due to weather;
- More accurate detailing;
- Non-shrinking and non-creeping at ambient temperatures;
- Formwork unnecessary;
- Termite-proof and rot-proof;
- Uniform quality;
- Economy in transportation and handling;
- Non-combustibility;
- Recyclable material.

The combination of the above-mentioned advantages can result in cost saving in construction.