THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

国家钢结构工程技术研究中心
National Engineering Technology Research Center for Steel Construction

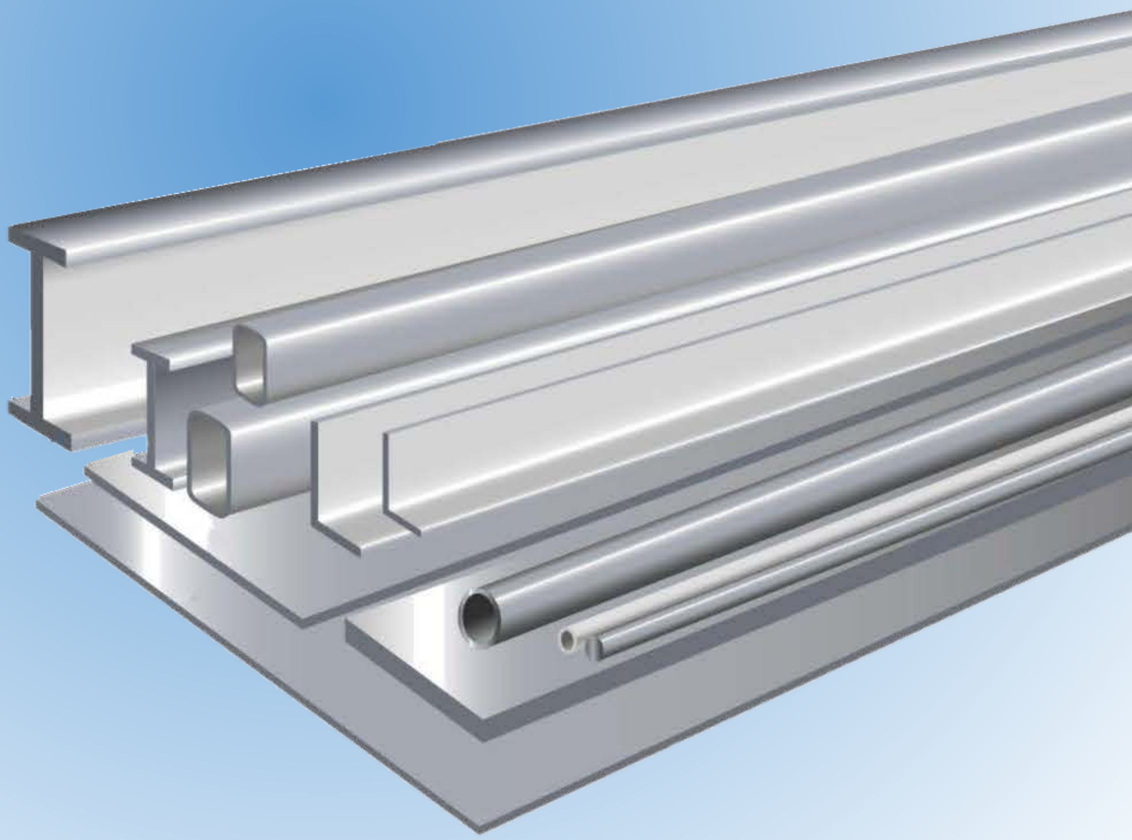
國家鋼結構工程技術研究中心香港分中心
Chinese National Engineering Research Centre
For Steel Construction (Hong Kong Branch)

Selection of Equivalent Steel Materials to European Steel Materials Specifications

Professional Guide: PG-003

Second Edition

K F Chung, H C Ho and W Feng



2021

HONG KONG CMSA
Constructional Metal Structures Association
香港建築金屬結構協會

CISA
中国钢铁工业协会

CONSTRUCTION INDUSTRY COUNCIL
建造業議會

Selection of Equivalent Steel Materials to European Steel Materials Specifications

K F Chung, H C Ho and W Feng

Professional Guide：PG-003

July 2021

Jointly published by

Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch)
The Hong Kong Polytechnic University
Chinese National Engineering Research Centre for Steel Construction
Hong Kong Constructional Metal Structures Association

Supported by

China Iron and Steel Association

Construction Industry Council, Hong Kong SAR

Printed by The Hong Kong Polytechnic University
ISBN: 978-962-367-872-8

Foreword

First Edition published in 2015

Among various international steel materials specifications, European steel materials specifications have been widely adopted in many countries all over the world owing to their high credibility and applicability levels. However, owing to differences in technological developments over the past 30 years, Chinese steel materials specifications have different acceptance criteria and follow different quality assurance procedures than is the case with European steel materials specifications. These technical differences cause practical difficulties to many design and construction engineers in accepting Chinese steel materials and structural products in international construction projects. The current situation, therefore, is highly unfavourable to the wide adoption overseas of Chinese steel materials, and this presents severe challenges to any substantial export growth of Chinese steel products.

The launching of this Professional Guide on "Selection of Equivalent Steel Materials to European Steel Materials Specifications" will help promote exports of high quality Chinese steel materials. The Guide tackles the practical problems encountered by thousands of design and construction engineers overseas in accepting Chinese steel materials as equivalent to European steel materials specifications by providing comprehensive technical information and the essential considerations involved in assessing the equivalence of steel materials from different countries. Through the use of this document, design and construction engineers are able to identify and readily establish equivalent Chinese steel materials.

As one of the publishers of this document, the Chinese National Engineering Research Centre for Steel Construction is delighted to witness the technological achievements displayed in the document. Publication of this document will contribute positively to continual research and development on high quality constructional steel by both the China Iron and Steel Industry and the Chinese Steel Construction Industry. Moreover, it will definitely promote further developments of modern steel construction technology in China and beyond.

Mr. Zhao-Xin HOU
Chief Engineer
Chinese National Engineering Research Centre for Steel Construction
Beijing, China

Foreword

First Edition published in 2015

With the support of national policies, the Chinese Steel Construction Industry has made rapid developments since 1990. A large number of enterprises with highly skilled structural steelwork designers and fabricators using advanced engineering technologies have emerged, pushing forward technological advances in the steel construction industry at an unprecedented pace. Since 2000, these enterprises have expanded out from their home bases to participate in many construction projects overseas, and contribute to the successes of many huge infrastructure developments in many parts of the world.

Owing to ever-increasing internationalization in the global construction market, it is important for Chinese steel materials to be used successfully in various foreign countries despite the fact that these countries have their own steel materials specifications. In recent years, it has become strategically important for Chinese steel materials to be directly accepted as equivalent European steel materials in many parts of the world. This particular development is generally thought to be an important breakthrough, supporting the continual business developments of these enterprises in the global construction market. It is also a direct response to the calls of the Chinese Steel Construction Industry for scientific and technological developments.

This Professional Guide on “Selection of Equivalent Steel Materials to European Steel Materials Specifications” presents design methodologies to establish selected steel materials as equivalent European steel materials. Based on the key technical requirements for various types of structural steelwork, chemical composition and mechanical properties have been examined systematically in classifying where equivalence lies.

This Professional Guide presents a comprehensive view on the equivalence of steel materials which is technically sound, and highly practical. It is expected that the acceptability of Chinese steel materials overseas and the competitiveness of Chinese Steel Construction Industry will be enhanced in securing international construction projects. Meanwhile, more research effort should be devoted by steel construction experts, senior design and construction engineers, and structural steel researchers in order to further promote the internationalization of the Chinese Steel Construction Industry.

Mr. Bing YAO
President
China Construction Metal Structure Association
Former Chief Engineer
Ministry of Construction, People’s Republic of China

Foreword

First Edition published in 2015

In recent years, the Chinese Iron and Steel Industry has made tremendous progress improving the qualities and outputs of steel materials, reducing the consumption of energy and the emission of greenhouse gases, and pioneering sustainable development in steel production. Nowadays, China is the largest steel producer in the world, and its annual production in 2013 is estimated to be 822 million metric tons*, being 54.3%* of world production. Moreover, it is well equipped with modern manufacturing facilities producing high quality steel materials with rigorous quality control and technological innovations. All of these are well recognized by the iron and steel industries of many countries. Hence, the Chinese Iron and Steel Industry has ever increasing influence on the iron and steel industries worldwide.

Steel materials are essential for construction in many countries, and steel construction standards are key engineering references for design, fabrication and construction of structural steelwork. At present, Chinese steel materials are not only able to fulfil the demands of the domestic construction industry in China, but are also exported to Southeast Asia, the European Community, the Americas, etc.. However, owing to the differences in various national structural steel specifications, Chinese steel materials often find difficulty in being accepted overseas. Moreover, many designers are not able to specify Chinese steel materials because of the lack of suitable design guidance. Hence, comparative analyses between European and Chinese steel materials specifications and advancement of the equivalence of high quality Chinese steel materials will not only improve the quality of Chinese steel materials, but also encourage technological collaboration and trade development between China and the European Community, and further facilitate the sustainable development of the Chinese Steel Constriction Industry.

Professor K.F. Chung, Professor S.P. Chiew and Mr. Y.H. Lee together with their research teams and engineering staff are committed in promoting the effective use of Chinese steel materials in construction worldwide. Based on their many years of experience in international engineering practice and structural engineering research in Hong Kong, Singapore, Macau, and other Asian countries, they have examined the technical requirements of European steel materials specifications as both explicitly and implicitly specified in Structural Eurocodes. All of these requirements have been assessed thoroughly and compared rigorously with those of Chinese steel materials, and the results are presented systematically in this Professional Guide on “Selection of Equivalent Steel Materials to European Steel Materials Specifications”.

This document is well written both technically and from the practical viewpoint, providing specific details on the effects of various chemical elements on the structural performance of steel materials. Different mechanical requirements for different types of steel materials are also identified. After comprehensive analyses of European and Chinese steel materials against various structural requirements, equivalence of European and Chinese steel materials is formulated in a rational manner. In general, this document will serve as the definitive technical reference for design and construction engineers using Chinese steel materials as equivalent European steel materials for construction purposes. The Guide will foster further research and development work on the equivalence of steel materials manufactured in different countries.

Mr. Zhen-Jiang LIU
Association Representative, Deputy President, and General Secretary
China Iron and Steel Association
Beijing, China

* Editor's note: Data provided by Chinese Iron and Steel Association in September 2014.

Foreword

First Edition published in 2015

As a meeting point of the East and the West, Hong Kong has the privilege of enjoying the best of both the East and the West. More importantly, Hong Kong is always able to learn from its contexts and constraints, and then develop its own practice to strive and succeed. At present, there are thousands of design offices, consultancy firms and engineering companies in Hong Kong, and many of them are regional headquarters and strategic offices of international companies in Asia. Hong Kong is truly an international city which is well connected to the rest of the world through flights, phones and the internet.

In respect of infrastructure developments, Hong Kong has witnessed the construction of many famous high-rise buildings and long span bridges designed and constructed by world renowned architects and engineers over the past 40 years. Through construction of these buildings and bridges, Hong Kong construction professionals have worked with thousands of constructional materials from all over the world. These include structural steel materials shipped from the U.K., European Communities, Japan, United States of America, Australia as well as China. Owing to the high levels of technological attainment and practical experience with British Standards, and more recently, Structural Eurocodes, Hong Kong design and construction engineers have been working on overseas construction projects since 1990.

In recent years, many large scale hotels and resorts have been designed and constructed in Macau by Hong Kong construction professionals, and a large number of leading Hong Kong companies of project managers, architects, engineers, surveyors, contractors, building materials suppliers as well as third-party inspection and testing agents have made tremendous contributions to the success of these construction projects. It should be noted that many of these hotels and resorts were designed to American practice, but built by Chinese contractors. Owing to the stringent specifications on building layouts, large enclosed spaces and short construction time, many of the building structures were of structural steelwork. Hence, Hong Kong construction professionals have successfully acquired first-hand professional experience of the latest international practice as well as in supporting the Chinese Construction Industry, in particular, the Chinese Steel Construction Industry.

The first edition of this Professional Guide entitled “Selection of Equivalent Steel Materials to European Steel Materials Specifications” is published in 2015 with a view to assist design and construction engineers in selecting suitable steel materials for structural steelwork which are designed to modern structural steel codes such as the Structural Eurocodes. After a comprehensive review of the chemical compositions and the mechanical properties of many constructional steel materials produced in accordance with the steel materials specifications of Australia, China, Japan, and U.S.A., equivalent steel materials have been identified which are readily accepted on construction projects. Technically, this Professional Guide provides an international level playing field for all high-quality steel materials produced to various national materials specifications enabling competition based purely on technical grounds. The Guide will generate a huge amount of interest among steel producers and structural steel designers in these countries, including China. Hong Kong design and construction engineers will be able to specify high quality steel materials and structural steelwork with reliable supply, good fabrication and high levels of economy for construction projects in Hong Kong and overseas. This will facilitate further development of Hong Kong as an International Engineering Design Centre for Infrastructure for Asia and beyond.

Professor Kwok-Fai CHUNG
President
Hong Kong Constructional Metal Structures Association
Hong Kong SAR, China

Foreword

First Edition published in 2015

Established in 2015, **The Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch)** aims to promote modern steel construction technology. Its main objectives are:

- To establish a high level technological platform to promote effective design and construction of modern building and civil engineering structures as well as sustainable infrastructure development in Hong Kong.
- To advance technological capabilities of Hong Kong Construction Industry in design and construction of super high-rise buildings, long span bridges and buildings of large enclosure using high performance materials in Hong Kong as well as in overseas.

It is dedicated to promote technological advancement and internationalization of both Hong Kong Construction Industry and Chinese Steel Construction Industry. It is actively engaged with international as well as national exchanges in research and development of steel construction. Its Industrial Collaborators are Development Bureau of the Government of Hong Kong Special Administrative Region, and the Construction Industry Council in Hong Kong.

It is our pleasure to publish the second edition of this Professional Guide. Based on the first edition of this Professional Guide, the following revisions and updates have been made:

a) key parameters for a wide range of steel materials produced in accordance with Russian steel materials specifications;
b) high strength S690 steels produced in accordance with Chinese, European and American steel materials specifications; and
c) latest steel materials specifications in various countries.

It should be noted that many constructional steel materials produced in accordance with the steel materials specifications of Russia have been incorporated into the Professional Guide as an extended scope of steel equivalence. We believe a wide dissemination of the technical information presented in this Professional Guide will greatly facilitate design and construction engineers as well as regulatory agents to use in effective use of steel in construction.

Professor Kwok-Fai CHUNG
Director
Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch)
The Hong Kong Polytechnic University
Hong Kong SAR, China

Foreword

The iron and steel industry is one of the most important industries for economic development in many countries in the world for a long time. In the past five years, the iron and steel industry in China has developed rapidly, and produced over 50% of the world steel production. With a continual upgrading of smelting technology and rolling equipment, the ranges of specifications of hot-rolled steel sections, steel plates, steel sheets, hollow steel sections, and sheet steel piles as well as other products have been greatly increased. Technological innovation in the iron and steel industry in China provides reliable steel products with guaranteed quality in various mechanical properties and dimensional precision. The iron and steel industry in China has also made huge contributions in the green and low-carbon development of the nation. A large variety of high-quality steel becomes available for realization of complex building structures in a highly efficient manner.

Since its establishment in 2015, the Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch) is a major driving force to promote the research and development of high-performance steel and modern steel construction technology through close collaborations among steel mills, steelwork fabricators, main contractors and design institutes. As a link between China and many parts of the world, the Hong Kong Branch has proactively carried out much research on mechanical properties and structural behaviour of steel structures, and their connections and joints. The scientific basis for an equivalent use of steel materials produced to various national materials specifications has been formulated, and the Professional Guide "Selection of Equivalent Steel Materials to European Steel Materials Specifications" was published in 2015. The Professional Guide provides a wide range of engineering options for design and construction engineers to use steel produced to various steel materials specifications effectively in construction projects. Hence, a scientifically based equivalent steel materials design method to identify suitable steel for replacement to various national steel materials specifications is provided.

We sincerely congratulate the Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch) to publish the second edition of this Professional Guide. We would like to pay tribute to Prof. K.F. Chung, its Director, and his team for their hard work. They have made outstanding contributions in promoting modern steel construction technology and the use of high-quality Chinese steel materials in construction. It is also expected that this Guide will be widely used by design and construction engineers of many international construction projects.

Mr. Jian-Guo ZHU
Director
Chinese National Engineering Research Centre for Steel Construction
Beijing, China

Foreword

Being the world's largest steel-manufacturing country, China’s steel production achieves a rapid growth since the dawn of this century. In recent years, it has produced more than 1.3 billion tons of steel every year, accounting for more than half of the world production. Owing to continual development in the steel-manufacturing process and technology of China's steel industry, the quality of Chinese steel continues to be enhanced. According to the National Strategic Development Policy on “**Carbon Peak and Carbon Neutrality**”, China's steel industry is currently being transformed into a technologically-enabled, sophisticated and green industry, providing a Chinese solution on the low-carbon development for the world's steel industry.

As a strong and versatile structural material, steel is widely used in large structures, such as industrial plants, stadia, transport terminals, bridges, skyscrapers, etc. in many countries all over the world. However, as different steel product specifications and technical standards are adopted in different countries, their engineers are unable to use Chinese steel effectively in design and construction. Hence, this results in a low proportion of Chinese steel adopted in construction overseas, despite of its high quality. Therefore, it is necessary to conduct a systematic comparative analysis on steel product specifications and standards which are widely adopted in construction in various countries, and to enable overseas engineers to clearly understand the advantages of Chinese steel and use them effectively in their construction projects.

The Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch) [CNERC] is committed to promoting the adoption of high-quality Chinese steel in international construction developments, and speeding up the globalistion of the of China's steel construction industry. Since 2011, members of CNERC conducted a series of applied research on the use of Chinese steel, providing systematic comparisons on steel-manufacturing processes as well as chemical compositions and mechanical properties of Chinese steel. In 2015, the Professional Guide entitled “**Selection of Equivalent Steel Materials to European Steel Materials Specifications**” was published.

In 2018, CNERC launched a project entitled “Use of high-quality Chinese steel to European structural steel design through equivalent use of steel” of the Chinese National Key Research and Development Programme which was supported by the State Ministry of Science and Technology of the People’s Republic of China. In this project, steel product specifications and their technical requirements of the European Union, Japan, the United States, Australia, and also Russia were comprehensively analyzed and compared. Through a number of construction projects in Hong Kong, Macau, Singapore, Malaysia and other Asian countries, it was demonstrated that high quality Chinese steel were able to meet various technical requirements of all the specifications in these regions.

The second edition of the Professional Guide “**Selection of Equivalent Steel Materials to European Steel Materials Specifications**” was published in 2021. It was established that the steel product specifications of China, the European Union, Japan, the United States, Australia, and Russia were compatible, and hence, equivalent. Through provision of a database for “*equivalent use of steel*”, CNERC promotes a wide application of high-quality Chinese steel overseas.

The China Iron and Steel Association recommends “**Selection of Equivalent Steel Materials to European Steel Materials Specifications**” as a definitive reference for engineers in selecting high quality Chinese steel. The Guide will foster research and development on steel-manufacturing technology, and facilitate improvements on steel quality worldwide. It also lays down a foundation for further development on “*equivalent use of steel*” in many countries in the world.

Mr. Wenbo HE

General Secretary and Executive President
China Iron and Steel Association
Beijing, China

Preface

First Edition published in 2015 *Second Edition published in 2021*

For many years, almost all steel structures in Hong Kong were designed to the British structural steel design code, BS5950, and all steel materials were specified correspondingly to British steel materials specifications such as BS4360. However, as early as the 1990s, non-British steel materials found their way to Hong Kong as well as to Singapore and other neighbouring cities in Southeast Asia. Occasionally, there were projects when contractors would use non-British steel materials, such as American, Australian, Japanese and Chinese steel materials. The changes ranged from merely using these materials for some members of temporary structures to replacement of complete beam-column frames of building structures. Over the years, many successful projects in Hong Kong benefited from good quality non-British steel materials, timely supply and delivery as well as improved structural economy. However, there were also a few bad examples of the use of non-British steel materials with inconsistent chemical composition, inadequate mechanical properties and lack of traceability.

In the 2000s, owing to large fluctuations in the costs of steel materials in the global markets, Chinese steel materials became practical alternatives to British steel materials in a number of construction projects in Asia, in particular, in Hong Kong, Macau and Singapore. During the drafting of the "Code of Practice for the Structural Use of Steel" for the Buildings Department of the Government of Hong Kong SAR, i.e. Hong Kong Steel Code from February 2003 to August 2005, it was decided necessary to devise a means to allow, or more accurately, to formalize, the use of Chinese steel materials as equivalent steel materials for structures which were originally designed to BS5950. Various parts of Chapter 3 of the Hong Kong Steel Code provided basic principles and considerations for qualifying as well as accepting steel materials manufactured to the following national materials specifications:

- American standards,
- Australian / New Zealand standards,
- Chinese standards, and
- Japanese standards.

Moreover, a simple and practical classification system for non-British steel materials was also introduced in the Hong Kong Steel Code in which the design strengths of these steel materials depended on adequacy of materials specifications as well as effectiveness of quality control during their production.

A similar use of non-British steel materials was also formally adopted in Singapore with the issue of a technical guide entitled "Design Guide on Use of Alternative Steel Materials to BS5950" in 2008, and then its revised version entitled "Design Guide on Use of Alternative

Structural Steel to BS5950 and Eurocode 3” in 2012 by the Building and Construction Authority of the Ministry of National Development. These Design Guides aimed to provide technical guidelines and design information on the use of non-British steel materials, and the classification system on various steel materials given in the Code of Practice on the Structural Use of Steel was adopted after minor modification. Under the provisions of these Design Guides, alternative steel materials not manufactured to British and European steel materials standards may be allowed in structural design based on the Structural Eurocodes for construction projects in Singapore.

Shortly after its establishment in July 2010, the Hong Kong Constructional Metal Structures Association collaborated closely with the Macau Society of Metal Structures to explore various issues related to the equivalence of steel materials, and their impacts on construction projects in both Hong Kong and Macau. With the support of the Chinese National Engineering Research Centre for Steel Construction in Beijing, an Expert Panel on the Effective Use of Equivalent Steel Materials in Building Construction was established. A meeting of 12 steel experts from China, Hong Kong and Macau was held on 26 January 2011 at the Hong Kong Convention and Exhibition Centre in Wan Chai, Hong Kong to i) identify the needs of the local construction industry, ii) establish possible supply chains of equivalent steel materials, and iii) formulate recommendations for rectification. Consequently, an Expert Task Committee was established in March 2011 to collect technical information on both the chemical composition and mechanical properties of steel materials produced by European countries and the U.K., Australia, China, Japan, and the United States of America for comparative analysis.

By September 2011, a number of steel materials specifications from various countries had been selected for further consideration according to their mechanical properties: yield strengths, tensile to yield strength ratios, elongation limits, toughness and weldability. The findings were presented to the Chinese Iron and Steel Association and the Chinese Steel Construction Society in March 2012, and it was decided to expand the scope of the comparative analysis to cover steel materials under various delivery conditions as well as product forms. Moreover, a scientific and yet practical basis for gauging the equivalence of steel materials should be formulated. After a number of meetings of members of the Expert Task Committee as well as discussions and exchanges with experienced engineers and steel experts in Hong Kong, Macau and China, a draft of the Professional Guide entitled “Selection of Equivalent Steel Materials to European Steel Materials Specifications” was compiled in September 2013 for international consultation.

During the Pacific Structural Steel Conference 2013 held in Singapore from 9 to 11 October 2013, many experienced engineers and steel experts as well as technical representatives of national steel construction associations were invited to join the International Advisory

Committee of the Professional Guide. They provided valuable technical comments on the draft document as well as recommendations to the Expert Task Committee on the overall direction for further development of the Professional Guide. After receiving many favourable and constructive comments, the international consultation was concluded in April 2014, and the finalized version of the Professional Guide was compiled in July 2014 after incorporating all comments as appropriate.

Through the use of the Professional Guide, selected steel materials manufactured to modern materials specifications of Australia/New Zealand, China, Japan, and the United States of America are fully endorsed to be equivalent to those steel materials manufactured to European steel materials specifications including EN 10025, EN 10149, EN 10210 and EN 10219. Moreover, these equivalent steel materials must achieve full compliance with the requirements on material performance and quality assurance to EN 10025 as detailed in the Professional Guide. Consequently, these equivalent steel materials can be readily employed on construction projects in which structural steelwork is designed to Structural Eurocodes EN 1993 and EN 1994. Hence, the Professional Guide provides an international level playing field for Chinese steel materials enabling them to compete directly with those steel materials from other countries for overseas construction projects.

The Professional Guide is jointly published by the Hong Kong Constructional Metal Structures Association, the Macau Society of Metal Structures and the Chinese National Engineering Research Centre for Steel Construction. The support from the following organizations for the publication of this document is gratefully acknowledged:

- China Iron and Steel Association
- Construction Industry Council, Hong Kong SAR
- Civil Engineering Laboratory of Macau, Macau SAR
- Singapore Structural Steel Society, Singapore

This Professional Guide has been compiled under the close supervision and general management of an Expert Task Committee led by Professor K.F. Chung. Technical comments on the draft document as well as recommendations on the overall development of the Professional Guide were also received from members of the International Advisory Committee. Various drafts of the document have been reviewed by experienced engineers and steel experts in Hong Kong, Macau and China as well as members of the International Advisory Committee. Contributions from members of both the International Advisory Committee and the Expert Task Committee are gratefully acknowledged.

International Advisory Committee

- **Mr. Jin-Dong CHI**
  Chinese Iron and Steel Association, Beijing, China
- **Mr. Yi LIU**
  Chinese Steel Construction Society, Beijing, China
- **Mr. Zhao-Xin HOU**
  Chinese National Engineering Research Centre for Steel Construction, Beijing, China
- **Professor Yong-Jiu SHI**
  Tsinghua University, Beijing, China
- **Professor Yi-Yi CHEN**
  Tongji University, Shanghai, China
- **Professor Guo-Qiang LI**
  Tongji University, Shanghai, China
- **Professor Jing-Tao HAN**
  University of Science and Technology Beijing, Beijing, China
- **Dr. Man-Chun TANG**
  T. Y. Lin International, U.S.A.
- **Dr. Robin Siu-Hung SHAM**
  AECOM Bridge Engineering, U.S.A. & Hong Kong SAR
- **Professor Reidar BJORHOVDE**
  American Society of Civil Engineers and American Institute of Steel Construction, U.S.A.
- **Professor David A NETHERCOT**
  Imperial College London, London, U.K.
- **Professor R. Mark LAWSON**
  The Steel Construction Institute, Ascots, U.K.
- **Professor Eiki YAMAGUCHI**
  Kyushu Institute of Technology, Kyushu, Japan
- **Professor Brian UY**
  New South Wales University, Sydney, Australia
- **Dr. Stephen HICKS**
  Heavy Engineering Research Association, Auckland, New Zealand
- **Professor Riccardo ZANDONINI**
  University of Trento, Trento, Italy

International Advisory Committee (continued)

- **Professor Richard Jat-Yuen LIEW**
  National University of Singapore, Singapore
- **Mr. Wan-Boon HO**
  Singapore Structural Steel Society, Singapore
- **Mr. Anthony Kin-Wah TAN**
  Singapore Structural Steel Society, Singapore
- **Er. Kaliannan THANABAL**
  Singapore Structural Steel Society, Singapore
- **Mr. David Shiu-Yuen NG**
  Institution of Structural Engineers - Malaysia Division, and
  Institution of Engineers Malaysia, Kuala Lumpur, Malaysia
- **Dr. Sai-Ping CHUI**
  Macau Society of Metal Structures, Macau SAR, China
- **Dr. Mun-Fong CHAN**
  Civil Engineering Consultants Co. Ltd., Macau SAR, China
- **Dr. Peng-Kong AO**
  Civil Engineering Laboratory of Macau, Macau SAR, China
- **Ir Julian Chun-Fai LEE**
  Construction Industry Council, Hong Kong SAR, China
- **Dr. Michael, Chi-Ho YAM**
  Hong Kong Constructional Metal Structures Association, Hong Kong SAR, China
- **Dr. Paul Heung-Fai LAM**
  Hong Kong Constructional Metal Structures Association, Hong Kong SAR, China
- **Ir Kwok-Tung LEUNG**
  Architectural Services Department, the Government of Hong Kong SAR, China
- **Ir Kai-Sing KWAN**
  Hong Kong Housing Department, the Government of Hong Kong SAR, China
- **Ir Alan Hoi-Ngan YAU**
  AECOM Building Structures, Hong Kong SAR, China
- **Mr. Kwong-Hung LAI**
  VSL Hong Kong Ltd., Hong Kong SAR, China
- **Dr. Ir Gary Siu-Kai CHOU**
  Chun Wo Construction and Engineering Co. Ltd., Hong Kong SAR, China

Expert Task Committee

- **Professor Kwok-Fai CHUNG**
  Hong Kong Constructional Metal Structures Association,
  Department of Civil and Environmental Engineering,
  The Hong Kong Polytechnic University, Hong Kong SAR, China
- **Dr. Sing-Ping CHIEW**
  Division of Structures and Mechanics, School of Civil and Environmental Engineering,
  Nanyang Technological University, Singapore
- **Ir Hoi-Yuen LEE**
  Hong Kong Constructional Metal Structures Association,
  formerly, AECOM Building Structures, Hong Kong SAR, China
- **Dr. Michael Chi-Ho YAM**
  Hong Kong Constructional Metal Structures Association,
  Department of Building and Real Estate,
  The Hong Kong Polytechnic University, Hong Kong SAR, China
- **Mr. Zhao-Xin HOU**
  Chinese National Engineering Research Centre, Beijing, China
- **Professor Yong-Jiu SHI**
  Tsinghua University, Beijing, China
- **Mr. Danny Hon-Yiu CHEUNG**
  Macau Society of Metal Structures, Macau SAR, China
- **Dr. Paul Heung-Fai LAM**
  Hong Kong Constructional Metal Structures Association,
  Department of Architecture and Civil Engineering,
  The City University of Hong Kong, Hong Kong SAR, China
- **Ir Man-Kit LEUNG**
  Architectural Services Department, the Government of Hong Kong SAR, China
- **Eng. Ken Wai-Kin CHOI**
  Structures and Buildings Department,
  Civil Engineering Laboratory of Macau, Macau SAR, China
- **Dr. Ho-Cheung HO**
  Hong Kong Constructional Metal Structures Association,
  Department of Civil and Environmental Engineering,
  The Hong Kong Polytechnic University, Hong Kong SAR, China
- **Dr. Augus Chi-Chiu LAM**
  Department of Civil and Environmental Engineering
  University of Macau, Macau SAR, China

Technical comments from the following organizations are also received:

- ArcelorMittal Commercial Sections, Luxembourg
  Mr. Jean-Claude GERARDY
- Continental Steel PTE Ltd., Singapore
  Mr. Melvin SOH
- Nanjing Iron & Steel Co., Ltd., China

Selection of Equivalent Steel Materials to European Steel Materials Specifications

K F Chung, H C Ho and W Feng

Professional Guide: PG-003

Executive Summary

This Professional Guide was prepared by Professor K.F. Chung, Dr. H.C. Ho and Ms. W. Feng of the Hong Kong Polytechnic University, Hong Kong. It is jointly published by the Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch), the Chinese National Engineering Research Centre for Steel Construction and the Hong Kong Constructional Metal Structures Association.

Owing to globalization, constructional steel materials find their way all over the world. It is an important part of the professional duties of structural engineers to specify steel materials according to various material specifications in accordance with the required material performance. Driven by the needs of improved cost effectiveness, steady supply and quality assurance of structural steelwork in construction projects, many engineers are confronted by the need to select steel materials from different sources which are rated as equivalent to European steel materials. Hence, it is necessary for design and construction engineers as well as engineers from regulatory authorities to seek technical guidance on the selection of equivalent steel materials. While such technical guidance is needed in many parts of the world, it is thought to be most urgently needed in a number of highly developed Asian countries and cities which are implementing huge infrastructure developments at present.

Through the use of this document, selected steel materials manufactured to the modern materials specifications of Australia/New Zealand, China, Japan, Russia, and the United States of America are fully endorsed as equivalent to those steel materials manufactured to European steel materials specifications, provided that all of these steel materials have been demonstrated to be in full compliance with the requirements for both material performance and quality assurance of European steel materials specifications as detailed in this document. Consequently, these equivalent steel materials will be readily employed on construction projects where the structural steelwork is designed to EN 1993 and EN 1994.

It should be noted that specific details relating to the following two essential requirements for equivalent steel materials are presented:

i) Material performance
   - mechanical strength for structural adequacy,
   - ductility for sustained resistances at large deformations,
   - toughness in term of energy absorption against impact, and
   - chemical composition and weldability to minimize risks of crack formation in welds.

ii) Quality assurance
   - demonstrated compliance with acceptable steel materials specifications,
   - demonstrated compliance with intensive routine testing with sufficient sampling

on both chemical composition and mechanical properties, and
- effective implementation of certified quality assurance systems.

Depending on the adequacy of material performance and demonstration of quality assurance during their production, steel materials with yield strengths ranging from 235 to 690 N/mm^2 are classified into three different classes:

i) Class E1 Steel Materials with a material class factor, γ_{Mc} equal to 1.0,

ii) Class E2 Steel Materials with γ_{Mc} equal to 1.1, and

iii) Class E3 Steel Materials with limited use.

The material class factor γ_{Mc} should be taken into account when determining the nominal values of strength parameters of the equivalent steel materials in structural calculations.

In general, this Professional Guide presents various key aspects of the engineering metallurgy of steel materials in order to describe the effects of both mechanical working and heat treatments on the structural performance of steel materials. The effects of various chemical elements on various mechanical properties and physical performances of the steel materials are also discussed. An overview of a number of general criteria which influence the choice of steel materials together with basic considerations on various product forms is also given while the overall selection considerations for design and construction engineers are also described. The essential requirements for establishing the equivalence of steel materials to European steel materials specifications for a wide range of product forms with different delivery conditions, including for those various parts of EN 10025, EN 10149, EN 10210, EN 10219 and other sources, are tabulated for easy reference.

In order to help design and construction engineers in selecting suitable equivalent steel materials, detailed design data for these equivalent steel materials from various national materials specifications are tabulated. Strength parameters of these equivalent steel materials for various product forms with different steel grades and plate thicknesses are tabulated to allow direct adoption in structural design.

A comprehensive list of acceptable steel materials with different delivery conditions and product forms produced by various countries are also provided in Appendix A while the most updated materials specifications for structural steel materials are presented in Appendix B. The quality control practices adopted by regulatory authorities in a number of countries and cities in Asia are also briefly described in Appendix C. Moreover, a number of worked examples on acceptance of various steel materials are presented in Appendix D.

Contents

Foreword		ii
Preface		xii
Executive Summary		xix
Contents		xxi
1	Introduction	1
1.1	Scope	1
1.2	Equivalent Steel Materials	1
1.3	World Supply of Steel Materials	2
1.4	Use of Non-British Steel Materials in Hong Kong, Macau and Singapore	5
1.5	Essential requirements for Equivalent Steel Materials	6
1.6	Design parameters	7
1.7	Overview	8
2	Engineering Metallurgy of Steel Materials	9
2.1	Steelmaking Process	10
2.2	Basic Concepts of Microstructures in Carbon Steels	12
2.2.1	Definition of constituents in steel	12
2.2.2	Iron-carbon phase diagram	15
2.2.3	Transformation of phases throughout the cooling process	16
2.3	Mechanical Working and Heat Treatments	18
2.3.1	Types of delivery conditions	18
2.3.2	Metallurgical aspects of rolling and heat-treatments	19
2.4	Chemical Composition	24
2.4.1	Effects on mechanical and material performance	24
2.4.2	Effects on weldability	29
2.5	Basic Material Properties of Steel Materials	30
2.6	Designation of Steel Grades	30
3	Equivalence of Steel Materials and Their Selection	31
3.1	Criteria Influencing Choice of Steel Materials	31
3.1.1	Basic considerations	31
3.1.2	Overall selection considerations	33

3.2	Equivalency of Steel Materials	34
3.2.1	Selection principles	35
3.2.2	Classification of steel materials	37
3.2.3	Additional material tests required for Class E2 Steel Materials	40
3.2.4	Steel materials with yield strengths larger than 690 N/mm^2	41
3.3	Material Performance Requirements to European Steel Materials Specifications	42
3.3.1	Structural steels	44
3.3.1.1	Plates	44
3.3.1.2	Sections	45
3.3.1.3	Hollow sections	46
3.3.1.4	Sheet piles	47
3.3.1.5	Solid bars	48
3.3.1.6	Strips for cold formed open sections	49
3.3.1.7	Strips for cold formed profiled sheetings	50
3.3.1.8	Stud connectors	51
3.3.1.9	Non-preloaded bolted assemblies	52
3.3.1.10	Preloaded bolted assemblies	54
3.3.1.11	Welding consumables	56
3.4	Quality Assurance Requirements to European Steel Materials Specifications	57
3.4.1	Factory Production Control System	57
3.4.1.1	Requirements for Factory Production Control System	57
3.4.1.2	Raw materials	58
3.4.1.3	Equipment	58
3.4.1.4	Verifications and tests	58
3.4.1.5	Monitoring of conformity	58
3.4.1.6	Testing with direct and indirect methods	58
3.4.1.7	Testing records	59
3.4.1.8	Treatment of products which do not conform	59
3.4.1.9	Record of verifications and tests	59
3.4.1.10	Traceability	59
4	Design Parameters of Equivalent Steel Materials	60
4.1	Product Forms of Equivalent Steel Materials	60
4.2	Design Parameters on Class E1 Equivalent Steel Materials	61
4.2.1	Class E1 Structural steels	61
4.2.2	Class E1 Thin gauge strips	67
4.2.3	Class E1 Connection materials	70
4.2.3.1	Class E1 Stud connectors	70

4.2.3.2	Class E1 Non-preloaded bolting assemblies	70
4.2.3.3	Class E1 Preloaded bolting assemblies	73
4.2.3.4	Class E1 Welding consumables	75
4.3	Design Parameters on Class E2 Steel Materials	77
4.3.1	Class E2 Structural steels	77
4.3.2	Class E2 Thin gauge strips	77
4.3.3	Class E2 Connection materials	78
4.3.3.1	Class E2 Stud connectors	78
4.3.3.2	Class E2 Non-preloaded bolting connections	78
4.3.3.3	Class E2 Preloaded bolting connections	79
4.3.3.4	Class E2 Welding consumables	79
4.4	Design Parameters on Class E3 Steel Materials	80
4.4.1	Class E3 Structural steels	80

References 81

Appendices 83

List of tables

Table 1.1	Annual crude steel production (mmt) of various countries of interest since 1980	3
Table 1.2	Major steel producing countries in 2013	4
Table 2.1	Typical functions of chemical elements in structural carbon steels	13
Table 2.2	Significations of critical points in iron-carbon phase diagram	15
Table 2.3	Typical microstructures of steels and their morphologies in cooling conditions	22
Table 2.4	Typical functions of chemical elements in structural carbon steels	28
Table 3.1	Classification system of various classes of steel materials	39
Table 3.2	Additional material tests required for demonstration of conformity	40
Table 3.3	Product forms	42
Table MR1	Material requirements for plates	44
Table MR2	Material requirements for sections	45
Table MR3	Material requirements for hollow sections	46
Table MR4	Material requirements for sheet piles	47
Table MR5	Material requirements for solid bars	48
Table MR6	Material requirements for cold formed open sections	49
Table MR7	Material requirements for cold formed profiled sheetings	50
Table MR8	Material requirements for stud connectors	51
Table MR9	Material requirements for non-preloaded bolted assembles	52
Table MR10	Material requirements for preloaded bolted assembles	54
Table MR11	Material requirements for welding consumables	56
Table 4.1	Product forms of various classes of equivalent steel materials	60
Table 4.2a	Design parameters of Structural steels to European (EN) specifications	61
Table 4.2b	Design parameters of Class E1 Structural steels to American (ASTM and API) specifications	62
Table 4.2c	Design parameters of Class E1 Structural steels to Japanese (JIS) specifications	63
Table 4.2d	Design parameters of Class E1 Structural steels to Australian/New Zealand (AS/NZS) specifications	64
Table 4.2e	Design parameters of Class E1 Structural steels to Chinese (GB) specifications	65
Table 4.2f	Design parameters of Class E1 Structural steels to Russian(GOST) specifications	66
Table 4.3a	Design parameters of Thin gauge strips to European (EN) specifications	67

Table 4.3b	Design parameters of Class E1 Thin gauge strips to American (ASTM) specifications	67
Table 4.3c	Design parameters of Class E1 Thin gauge strips to Japanese (JIS) specifications	67
Table 4.3d	Design parameters of Class E1 Thin gauge strips to Australian/New Zealand (AS/NZS) specifications	68
Table 4.3e	Design parameters of Class E1 Thin gauge strips to Chinese (GB) specifications	68
Table 4.3f	Design parameters of Class E1 Thin gauge strips to Russian(GOST) specifications	69
Table 4.4	Design parameters Class E1 Stud connectors to European (EN), American (AWS), Japanese (JIS), Australian/New Zealand (AS/NZS), Chinese (GB) and Russian (GOST) specifications	70
Table 4.5a	Design parameters of non-preloaded bolts to European (EN) specifications	70
Table 4.5b	Design parameters of Class E1 non-preloaded bolts to American (ASTM) specifications	71
Table 4.5c	Design parameters of Class E1 non-preloaded bolts to Japanese (JIS) specifications	71
Table 4.5d	Design parameters of Class E1 non-preloaded bolts to Australian/New Zealand (AS) specifications	71
Table 4.5e	Design parameters of Class E1 non-preloaded bolts to Chinese (GB) specifications	71
Table 4.5f	Design parameters of Class E1 non-preloaded bolts to Russian (GOST) specifications	72
Table 4.6a	Design parameters of preloaded bolts to European (EN) specifications	73
Table 4.6b	Design parameters of Class E1 non-preloaded bolts to American (ASTM) specifications	73
Table 4.6c	Design parameters of Class E1 preloaded bolts to Japanese (JIS) specifications	73
Table 4.6d	Design parameters of Class E1 preloaded bolts to Australian/New Zealand (AS) specifications	74
Table 4.6e	Design parameters of Class E1 preloaded bolts to Chinese (GB) specifications	74
Table 4.6f	Design parameters of Class E1 Preloaded bolts to Russian (GOST) specifications	74
Table 4.7a	Design parameters of welds made of European (EN) specifications	75
Table 4.7b	Design parameters of Class E1 welds made of American (AWS)	75

	specifications	
Table 4.7c	Design parameters of Class E1 welds made of Japanese (JIS) specifications	75
Table 4.7d	Design parameters of Class E1 welds made of Australian/New Zealand (AS) specifications	75
Table 4.7e	Design parameters of Class E1 welds made of Chinese (GB) specifications	76
Table 4.7f	Design parameters of Class E1 Welds made of Russian (GOST) welding consumables	76
Table 4.8	Design parameters of Class E2 Structural steels	77
Table 4.9	Design parameters of Class E3 Structural steels	80

List of figures

Figure 1.1	Annual crude steel production proportions of five countries of interest in 2013	4
Figure 2.1	A diagrammatic presentation of steelmaking processes	11
Figure 2.2	Principle crystal types and photomicrographs of microstructures in carbon steels	14
Figure 2.3	Iron-carbon phase diagram	15
Figure 2.4	Iron-carbon phase diagram of hypoeutectoid steel	17
Figure 2.5	Comparison between various delivery conditions	19
Figure 2.6	Schematic illustration of change in microstructure during hot rolling	20
Figure 2.7	Schematic representation of recovery, recrystallization and grain growth	21
Figure 2.8	Designation of steel grade according to EN 10027-1	30

Section 1 Introduction

1.1 Scope

This document presents essential technical guidance to design and construction engineers as well as engineers from regulatory authorities on the selection of equivalent steel materials conforming to European steel materials specifications.

It also gives essential requirements for the equivalence of steel materials in respect of both material performance and quality assurance for all steel materials which are intended to accord with European structural steel design codes.

1.2 Equivalent Steel Materials

Equivalent steel materials are steel materials not manufactured to European steel materials specifications, and therefore not covered in EN1 993 and EN 1994 by default.

Owing to globalization, constructional steel materials find their way all over the world. It is an important part of the professional duties of structural engineers to specify steel materials according to various material specifications in accordance with the required material performance levels explicitly as well as those implicitly assumed in design codes. Driven by improved cost effectiveness, steady supply of structural steelwork, and assured material quality in construction projects, many engineers are often confronted by the need to select steel materials from different sources which are equivalent to European steel materials. Hence, it is necessary for design and construction engineers as well as engineers from regulatory authorities to seek technical guidance on the selection of equivalent steel materials. While such technical guidance is needed in many parts of the world, it is considered to be most urgently needed in a number of highly developed Asian countries and cities which are implementing huge infrastructure developments at present.

While the basic principles of equivalence are presented Chapter 3, it should be noted that owing to many differences and discrepancies in both the chemical composition and the material performance of steel materials, the equivalence of steel materials manufactured to different national materials specifications should not be taken for granted. Nevertheless, this document covers many of the steel materials manufactured by the following six countries of interest:

a) United States of America,
b) Japan,
c) Australia / New Zealand,
d) China, and
e) Russian.

These equivalent steel materials can be readily employed on construction projects in which the structural steelwork is designed to EN 1993 and EN 1994.

1.3 World Supply of Steel Materials

Steel materials are international commodities which are commonly shipped thousands of miles from where they were manufactured to wherever there is a market. The World Steel Association (www.worldsteel.org) is one of the largest industry associations in the world. It represents approximately 85% of global steel production including steel producers, national and regional steel industry associations, and steel research institutes. Based on the statistics archive of the World Steel Association, Table 1.1 presents the annual crude steel production of Australia, China, Japan, the United Kingdom, the United States of America, and Russia from 1980 to 2021 together with total world production.

It is shown that Australia, Japan, the U.K., the U.S.A., and Russia tend to maintain their annual crude steel production tonnages at a broadly constant level with minimal growth as a whole.

However, owing to the rapid development of the iron and steel industry in China since the 1980's, the steel production capacity increased markedly over the last 30 years. It should be noted that as a large number of steel mills in many parts of China upgraded their production facilities and commissioned new production plants, the annual crude steel production of China increased steadily from 37.1 mmt (million metric tons) in 1980 to 1064.7 mmt in 2020, i.e. an increase of approximately 28.7 over a period of 40 years. Its annual crude steel production exceeded 100 mmt in 1996, 200 mmt in 2003, 500 mmt in 2008, and then 1000 mmt in 2020. Over 45 % of the steel materials in the world have been produced in China since 2010.

According to recent statistical data of the World Steel Association, the major steel-producing countries in the world in 2021 are presented in Table 1.2. It should be noted that the annual steel production of China reached 1032.8 mmt, accounting for 52.9% of world production. Hence, it is important for design and construction engineers in Asia to be able to take advantages of the huge supply of Chinese steel materials.

Table 1.1 Annual crude steel production (mmt) of various countries of interest since 1980

Year	Australia	China	Japan	U.K.	U.S.A.	Russia	World production
1980	7.6	**37.1**	111.4	11.3	101.5	—	568.5
1981	7.6	35.6	101.7	15.6	109.6	—	558.7
1982	6.4	37.2	99.5	13.7	67.7	—	498.4
1983	5.7	40.0	97.2	15.0	76.8	—	511.2
1984	6.3	43.5	105.6	15.1	83.9	—	556.0
1985	6.6	46.8	105.3	15.7	80.1	—	564.2
1986	6.7	52.2	98.3	14.7	74.0	—	553.4
1987	6.1	56.3	98.5	17.4	80.9	—	573.6
1988	6.4	59.0	105.7	19.0	90.7	—	617.1
1989	6.7	61.6	108.0	18.7	88.9	—	625.8
1990	6.7	66.4	110.3	17.8	89.7	—	616.0
1991	6.1	71.0	109.6	16.5	79.7	—	600.8
1992	6.8	80.9	98.1	16.2	84.3	67.0	719.8
1993	7.9	89.6	99.6	16.6	88.8	58.3	727.6
1994	8.4	92.6	98.3	17.3	91.2	48.8	725.1
1995	8.5	95.4	101.6	17.6	95.2	51.6	752.3
1996	8.4	**101.2**	98.8	18.0	95.5	49.2	750.1
1997	8.8	108.9	104.5	18.5	98.5	48.5	799.0
1998	8.9	114.6	93.5	17.3	98.7	43.8	777.3
1999	8.2	124.0	94.2	16.3	97.4	51.5	789.0
2000	7.1	128.5	106.4	15.2	101.8	59.1	848.9
2001	7.0	151.6	102.9	13.5	90.1	59.0	851.1
2002	7.5	182.4	107.7	11.7	91.6	59.8	904.2
2003	7.5	**222.3**	110.5	13.3	93.7	61.5	969.9
2004	7.4	282.9	112.7	13.8	99.7	65.6	1071.5
2005	7.8	353.2	112.5	13.2	94.9	66.1	1144.1
2006	7.9	419.1	116.2	13.9	98.6	70.8	1247.2
2007	7.9	489.3	120.2	14.3	98.1	72.4	1346.1
2008	7.6	**500.3**	118.7	13.5	91.4	68.5	1329.0
2009	5.2	567.8	87.5	10.1	58.2	60.0	1224.0
2010	7.3	**638.7**	109.6	9.7	80.5	66.9	1435.3
2011	6.4	702.0	107.6	9.5	86.4	68.9	1539.9
2012	4.9	731.0	107.2	9.6	88.7	70.2	1562.3
2013	4.7	822.0	110.6	11.9	86.9	69.0	1652.3
2014	4.6	822.3	110.7	12.0	88.2	71.5	1674.0
2015	4.9	803.8	105.1	10.9	78.8	70.9	1625.1
2016	5.3	807.6	104.8	7.6	78.5	70.5	1632.8
2017	5.3	870.9	104.7	7.5	81.6	71.5	1735.9

(To be continued)

(Continued)

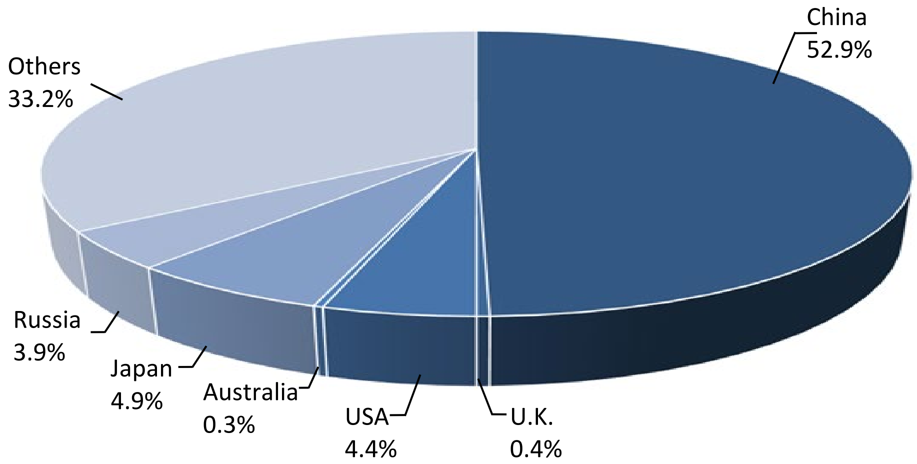
Year	Australia	China	Japan	U.K.	U.S.A.	Russia	World production
2018	5.7	929.0	104.3	7.3	86.6	72.1	1826.6
2019	5.5	995.4	99.3	7.2	87.8	71.7	1875.3
2020	5.5	**1064.7**	83.2	7.1	72.7	71.6	1880.4
2021	5.8	1032.8	96.3	7.2	85.8	75.6	1951.9

Note: mmt denotes million metric tons.

Table 1.2 Major steel producing countries in 2021

Ranking	Country	Annual crude steel Production (mmt)	Proportion (%)	
1	China	1032.8	52.9%	83.2
2	India	118.2	6.1%	
3	Japan	96.3	4.9%	
4	United States	85.8	4.4%	
5	Russia	75.6	3.9%	
6	South Korea	70.4	3.6%	
7	Turkey	40.4	2.1%	
8	Germany	40.1	2.1%	
9	Brazil	36.2	1.9%	
10	Iran	28.5	1.5%	
Total production in the world		1951.9		

Moreover, Figure 1.1 illustrates the proportions of the annual steel production of the five countries of interest in 2021.



Total world production is 1951.9 mmt

Figure 1.1 Annual crude steel production proportions of six countries of interest in 2021

1.4 Use of Non-British Steel Materials in Hong Kong, Macau and Singapore

For many years, almost all steel structures in Hong Kong were designed to the British structural steel design code, BS5950, and all the steel materials were specified correspondingly to the British steel materials specifications such as BS4360. However, as early as the 1990s, non-British steel materials found their way to Hong Kong as well as to neighbouring cities in Southeast Asia. Occasionally, there were projects on which contractors would like to use non-British steel materials, such as Japanese, Australian and Chinese steel materials. The proposed changes ranged from merely adopting these steel materials for some members of temporary structures, to the replacement of complete beam-column frames of building structures. Over the years, many successful projects were reported in Hong Kong which benefited from good quality non-British steel materials, timely supply and delivery as well as improved structural economy. However, a few bad examples of using non-British steel materials also occurred with inconsistent chemical composition, inadequate mechanical properties and a lack of traceability.

In the 2000s, owing to large fluctuations in the costs of steel materials in the global markets, Chinese steel materials became practical alternatives to British steel materials on a number of construction projects in Asia, in particular, in Hong Kong, Macau and Singapore. During the drafting of the Code of Practice for the Structural Use of Steel for the Buildings Department of the Government of Hong Kong SAR, i.e. Hong Kong Steel Code, from February 2003 to August 2005, it was decided necessary to devise a means to allow, or more accurately, to formalize the use of Chinese steel materials as equivalent steel materials for structures which were originally designed to BS5950. Various parts of Chapter 3 of the Hong Kong Steel Code provide basic principles and considerations for qualifying and accepting steel materials manufactured to the following national materials specifications:

- American standards,
- Japanese standards,
- Australian / New Zealand standards,
- Chinese standards, and
- Russian standards.

As endorsed by the Buildings Department of the Government of Hong Kong SAR, the following classification system for non-British steel materials was introduced in the Hong Kong Steel Code in which the design strengths of these non-British steel materials depend on a material factor, γ , which is taken to be:

a) 1.0 when the steel materials are demonstrated to i) comply with one of the reference materials specifications listed in the Hong Kong Steel Code, ii) satisfy various material requirements, and iii) be produced by a manufacturer with an acceptable Quality Assurance system; this is a Class 1 steel material and no additional material tests are required before use.

b) 1.1 when the steel materials are demonstrated to be not manufactured to one of the reference materials specifications listed in the Hong Kong Steel Code, but are produced by a manufacturer with an acceptable Quality Assurance system; these are Class 2 steel materials. It should be noted that these steel materials should be tested systematically according to specific sampling rates before use in order to demonstrate compliance with the relevant reference materials specifications.

The Hong Kong Steel Code became mandatory in August 2005, and the material classification system of non-British steel materials became widely adopted in Hong Kong, Macau and other Asian countries. The Code was revised in 2011 to cover more product forms.

In 2008, the local regulatory agent in Singapore, namely, the Building and Construction Authority of the Ministry of National Development, published a technical guide entitled "Design Guide on Use of Alternative Steel Materials to BS5950". This Design Guide aimed to provide technical guidelines and design information on the use of non-British steel materials, and the classification system for various steel materials given in the Hong Kong Steel Code was adopted after modification. Under the provisions of this Design Guide, alternative steel materials not manufactured specifically to British Standards may be allowed for structural design based on BS5950 for construction projects in Singapore.

Moreover, in order to establish quality control, this Design Guide outlines both the material performance and the quality assurance requirements to be imposed on all steel materials, including those manufactured to British Standards, which are proposed for use in accordance with BS5950 in the context of Singapore. Design strengths of various acceptable non-British steel materials were tabulated for practical design. It should be noted that in 2012, the document was revised and re-titled as "Design Guide on Use of Alternative Structural Steel to BS5950 and Eurocode 3".

It is considered necessary to provide comprehensive guidance on the use of equivalent steel materials to design and construction engineers as well as engineers in regulatory bodies worldwide. This facilitates equivalent steel materials to be readily employed on construction projects in which the structural steelwork is designed to EN 1993 and EN1994.

1.5 Essential Requirements for Equivalent Steel Materials

The use of equivalent steel materials depends solely on their classification which is determined in accordance with their demonstrated compliance to the essential requirements on both material performance and quality assurance:

a) Material performance

Meeting material performance requirements of relevant European steel materials specifications is essential with respect to the dimensional, mechanical, physical and other relevant properties of equivalent steel materials to ensure their adequacy for use with structural design based on EN 1993 and EN 1994.

b) Quality assurance requirements

It is also essential for manufacturers of equivalent steel materials to demonstrate effective implementation of appropriate quality assurance during their manufacturing process as stipulated in relevant European steel materials specifications to ensure their reliability for use with structural design based on EN 1993 and EN 1994.

1.6 Design Parameters

All the key parameters in this document are defined as follows:

R_{eH}	Minimum yield strength	in accordance with EN 10025-1
$R_{p0.2}$	0.2% proof strength	
R_m	Tensile strength	
A	Minimum elongation at fracture	

f_y	Nominal value of yield strength	in accordance with EN 1993-1-1
f_u	Nominal value of ultimate tensile strength	

γ_{MC} Material class factor

ε_u Ultimate strain corresponding to f_u

ε_f Strain at fracture (which is taken as the same value of the minimum elongation, A, shown above)

It should be noted that in EN 1993-1-1, the following definitions of key parameters are adopted:

- Nominal value of yield strength, f_y

  $f_y = R_{eH}$ (Clause 3.2.1)

- Nominal value of ultimate tensile strength, f_u

  $f_u = R_m$ (Clause 3.2.1)

- Design strength $= f_y / \gamma_M$

  where γ_M is the partial factor of safety, and its value depends on the type of failure under consideration according to Clause 6.1.

It should be noted that there is no symbol for design strength, and f_y / γ_M is used instead.

With the introduction of the material class factor, γ_{MC}, for the use of equivalent steel materials as fully illustrated in Section 3.2 of this document, the following equations should be adopted:

- Nominal value of yield strength, f_y

$$f_y = R_{eH} / \gamma_{MC}$$

- Nominal value of ultimate tensile strength, f_u

$$f_u = R_m / \gamma_{MC}$$

- Design strength = f_y / γ_M

where γ_M is the partial factor of safety, and its value depends on the type of failure under consideration according to Clause 6.1 of EN 1993-1-1.

1.7 Overview

An overview of the chapters of this document is as follows:

Chapter 2 presents various key aspects of the engineering metallurgy of steel materials in order to describe the effects of both mechanical working and heat treatments on the structural performance of steel materials. The effects of various chemical elements on the mechanical and other types of performance of the steel materials are also discussed.

Chapter 3 discusses a number of general criteria which influence the choice of steel materials together with basic considerations on various product forms, and the overall selection considerations for design and construction engineers are also described. The essential considerations behind the selection principles for establishing equivalence of steel materials to European steel materials specifications for a wide range of product forms with different delivery conditions are also presented. Depending on the adequacy of material performance and demonstration of quality assurance during manufacturing processes, equivalent steel materials are classified into three different material classes, namely, Classes E1, E2 and E3 Steel materials. Moreover, materials requirements given in various parts of EN 10025, EN 10149, EN 10210 and EN 10219 as well as in other sources are summarized in tabulated format, and these are presented systematically in Tables MR1 to MR11 for easy reference. Details of a quality assurance system given in EN 10025 are also discussed.

Chapter 4 describes the classification of equivalent steel materials, and presents design data for those steel materials which have been demonstrated to meet the essential requirements on material performance and quality assurance for equivalence of steel materials as detailed in Chapter 3. Design parameters of these equivalent steel materials of various product forms with different steel grades and plate thicknesses are also tabulated in Tables 4.2 to 4.11 to allow direct adoption for the design of structural steelwork in accordance with European steel materials specifications.

A comprehensive list of acceptable steel materials with different delivery conditions and product forms produced by various countries are also provided in Appendix A while the most updated materials specifications for structural steel materials are presented in Appendix B. The quality control practices adopted by regulatory authorities in a number of countries and cities in Asia are also briefly described in Appendix C. Moreover, a total of seven worked examples on selection of equivalent steel materials are provided in Appendix D.

Section 2 Engineering Metallurgy of Steel Materials

Engineers should process some knowledge on the metallurgy of carbon steels, the most commonly used constructional steel materials. This Chapter presents key aspects of the engineering metallurgy of steel materials, and describes and relates the effects of both mechanical working and heat treatments on the structural performance of these steel materials.

It should be noted that the mechanical properties of the steel materials depend primarily on the following:

- Mechanical working and heat treatments

  Mechanical working and heat treatments involve controlled heating and cooling of steel materials under mechanical rolling to change their physical and mechanical properties under specific pre-assigned chemical compositions. It is well known that the mechanical properties of the steel materials depend strongly on their microstructures obtained throughout the heat treatment and the subsequent cold working processes, which are so formed as to achieve good hardened steel materials with high strengths and high ductility.

- Chemical compositions

  Structural steels are a mixture of iron and carbon with varying amounts of Manganese, Phosphorus, Sulphur, and Silicon. These and many other elements are either unavoidably present or intentionally added in various combinations to achieve specific characteristics and properties of the finished products. It should be noted that the chemical compositions of the steel materials are fundamental to their mechanical properties. The effects of various chemical elements on the mechanical properties as well as the material performances of the steel materials are summarized below in Section 2.4.

Further details on these important topics are presented in the following sections.

2.1 Steelmaking Process

Steelmaking is to produce steel from iron-rich raw materials. The modern steelmaking process consists of the following two stages, and the entire process is sketched out in a flow diagram as shown in Figure 2.1.

- Primary steelmaking

  There are two main types of steelmaking furnaces in this process. One is a basic oxygen furnace, in which molten pig iron from a blast furnace and steel scrap are rapidly converted into steel with desired carbon content and temperature. The energy for converting materials is provided by the oxidation of Carbon (C), Silicon (Si), Manganese (Mn), Phosphorus (P) and Iron. When the oxygen lance blows high-purity oxygen over the metal mixture, Carbon inside the furnace forms carbon dioxide in form of gas bubbles. Meanwhile, other impurities are oxidized to form slags by adding slag-making materials like lime, quartz and fluorite. This is regarded as an impurity removal process.

  The other is an electric arc furnace, in which the particularly sorted scrap steel and/or the direct reduced iron (DRI) are/is melted by electric arcs to produce steel with more desirable quality under a more accurate temperature. Heat is mainly supplemented by the electric resistance of the metal and radiation of the electrical arc itself. Compared with steelmaking in basic oxygen furnaces, that in electric furnaces the temperature is more accurate and the oxidation process is easier to control, which can avoid oxidizing useful alloying elements. Therefore, an electric arc furnace is normally used for alloy steel, high-quality steel and some special steel.

- Secondary steelmaking

  After tapping of steel from a primary steelmaking process, the molten steel is refined for improved quality by ladle metallurgy, and then, continuously cast into a pre-designed shape, commonly known as the secondary steelmaking process or ladle metallurgy.

  Secondary steelmaking is normally performed in ladles, which are used for holding and transporting liquid steel. In a ladle furnace, liquid steel is reheated through electric power conducted by graphite electrodes. With an inert gas purging through a purge plug, generated gas bubbles continuously transfer the impure gases and inclusions of molten steel into the top slag layer. Another function of purging inert gas is stirring the molten steel to promote homogenization. Slagging and alloy elements adjusting are also performed in this period.

  A vacuum degasser is a tank that can contain the ladle furnace. The main function of a vacuum degasser is removing residual gases(N_2,H_2,O_2), especially Hydrogen. During operations at the vacuum degasser, the liquid steel is stirred to promote homogenization by percolating argon gas through a single refractory stir plug arrangement in the bottom of the ladle. The bath agitation under a vacuum is also helpful for the further removal of inclusions. The next process is wire feeding, in order to remove residual O_2 and Sulphur in the liquid steel, finely adjusting the composition and changing form of inclusions. By adopting those operations, including de-oxidation reaction, vacuum degassing, alloy addition, removal or chemistry modification of inclusions, and homogenization, the quality of steel products is tightly controlled.

Subsequently, the ladle with molten steel is transferred to ladle turret preparing to continuously cast via tundish. In modern steelmaking, the continuous casting has almost replaced the conventional casting that is interrupted pouring ingots in moulds. On the mechanization production line, the molten steel is continuously distributed into a series of moulds. The inside dimension of each hollow mould is consistent with the predetermined section. The casting metal then moves through a set of rollers under water spray for full solidification, and be cut to size by flame-cutting torches or mechanical shearing in the form of bloom, billet, or slab. It usually needs a precisely controlled rolling and a reheated process for end uses, which will be described later in this chapter.

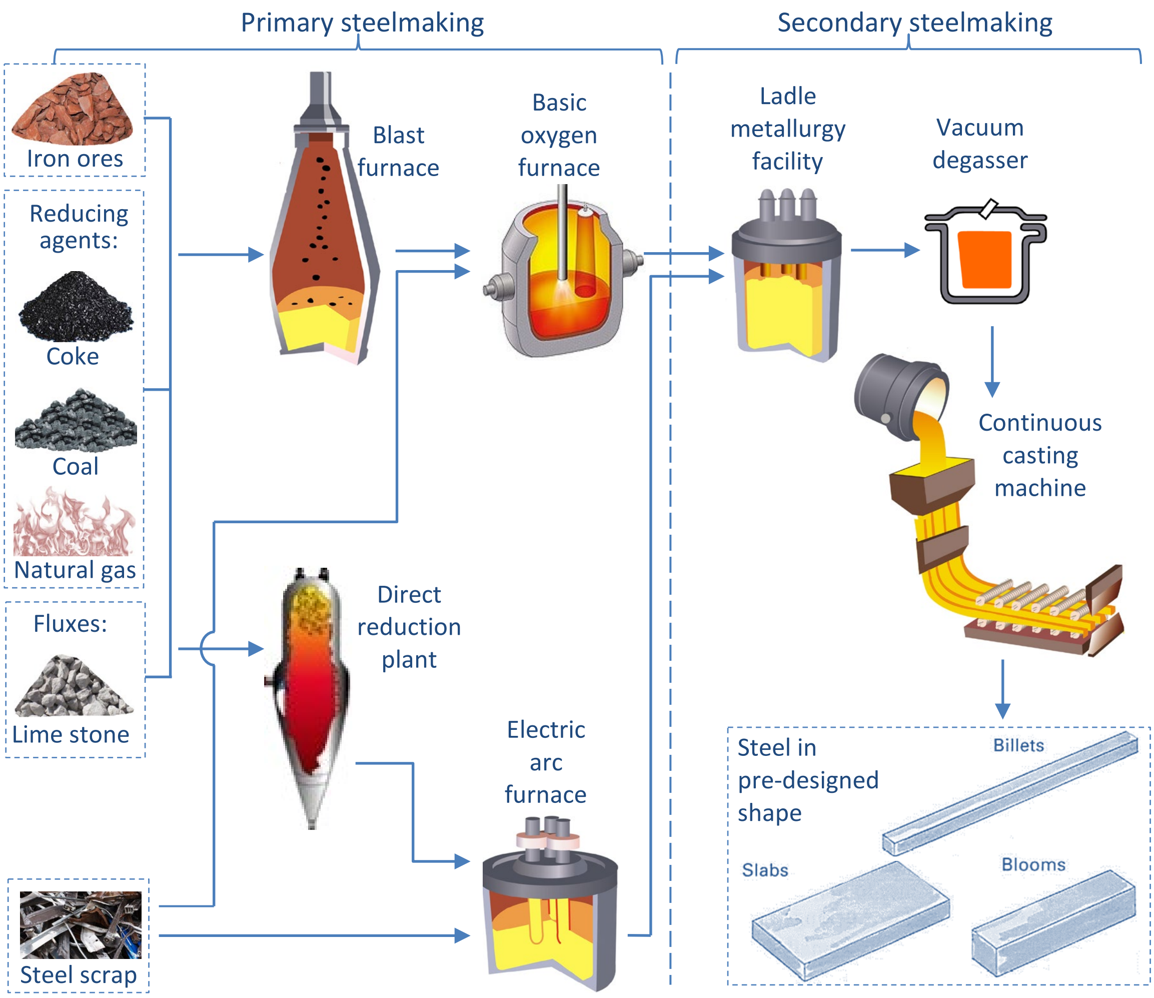


Figure 2.1 A diagrammatic presentation of steelmaking processes

2.2 Basic Concepts of Microstructures in Carbon Steels

Metals are crystalline in nature. Constituents in steel mainly exist as phases, or as aggregates, i.e., assemblages of phases. To introduce properties of primarily existed constituents, the effects of manganese and other alloy elements are neglected.

2.2.1 Definition of constituents in steel

Different kinds of microstructures make different contributions to mechanical properties of carbon steels. Carbon contents and qualitative effects of several key microstructural phases are indicated in Table 2.1. Meanwhile, their definitions and appearance are described as follows:

a) Austenite

Austenite is a solid solution dissolving carbon in face-centred cubic iron that contains up to a maximum content of 2.14% carbon, also known as the gamma-phase iron (γ-Fe). It is ductile and soft with a certain tensile strength in the high-temperature zone. The microscopic appearance of austenite is always large-grained, as shown in Figure 2.2a.

b) Ferrite

Ferrite is a solid solution of quite limited carbon solubility in body-centred cubic crystal structure consisting of at most 0.022% carbon, also known as the alpha-phase iron (α-Fe). Like the pure iron, ferrite is very ductile and soft with a low tensile strength. The ferrite microgram shown in Figure 2.2b is polyhedral gains.

c) Cementite

Cementite, or iron carbide with the chemical formula Fe_3C, is an intermetallic compound of iron and carbon. As a relatively high-carbon steel that contains 6.67% carbon, cementite is very hard and brittle. As shown in the micrograph of Figure 2.2c, it appears as a brilliant white network or needle-like around pearlite in slow cooling.

d) Pearlite

Pearlite is an aggregate of ferrite and cementite, which is an intimate mixture resulted from the eutectoid reaction when austenite of 0.76% carbon is slowly cooled below 727°C (the eutectoid temperature). As the two phases are alternatively arranged and uniformly distributed in the lamellar microstructure of pearlite (see Figure 2.2d), pearlite exerts the maximum hardening power with relatively good ductility and high strength.

e) Martensite

Martensite is an interstitial supersaturated solid solution of carbon with a highly strained body-centred tetragonal lattice. It is formed by the rapid cooling of austenite, also called quenching. The cooling rate is too high to let carbon atoms diffuse out of the crystal structure to form cementite. Martensite is the hardest transformation product of austenite, having lath shaped (C%＜0.6%) and lenticular shaped (C%＞1%) crystal grains (see Figure 2.2e), or a mix of the two shapes (0.6＜C%＜1%) .

Since martensite is a metastable phase of steel, it is usually reheated to relieve cooling stresses and minimize cracking, and to obtain a stable microstructure of the so-called tempered martensite (see Figure 2.2g).

f) Bainite

In addition to pearlite and martensite, bainite is another micro-constituent resulted from the decomposition of austenite. It forms in a moderate cooling rate that is faster to suppress the transformation from austenitic to ferrite and pearlite, but not fast enough to form martensite. In consequence, bainite is both harder and tougher than pearlite, but not so hard as martensite. Figure 2.2f shows the microstructural appearance as featherlike and acicular respectively for so-called "upper bainite" and "lower bainite", according to the temperature range of the transformation.

Table 2.1 Influence of microstructural constituents on properties of steels

Constituents	Carbon content (wt%)	Tensile strength	Ductility	Toughness	Hardness	Weldability	Anti-corrosion
Austenite	*Max 2.140*	↓	↑	↑	↓	↓	↑
Ferrite	*Max 0.022*	↓↓	↑	-	↓↓	↑	-
Cementite	*6.700*	↑↑	↓↓	↓↓	↑↑	↓↓↓	-
Pearlite	*0.760*	↑	↓	-	↑	↓	-
Bainite	-	↑↑	-	↑	↑↑	↓	-
Tempered Martensite	-	↑↑↑	-	↑↑	↑↑↑	↓	-

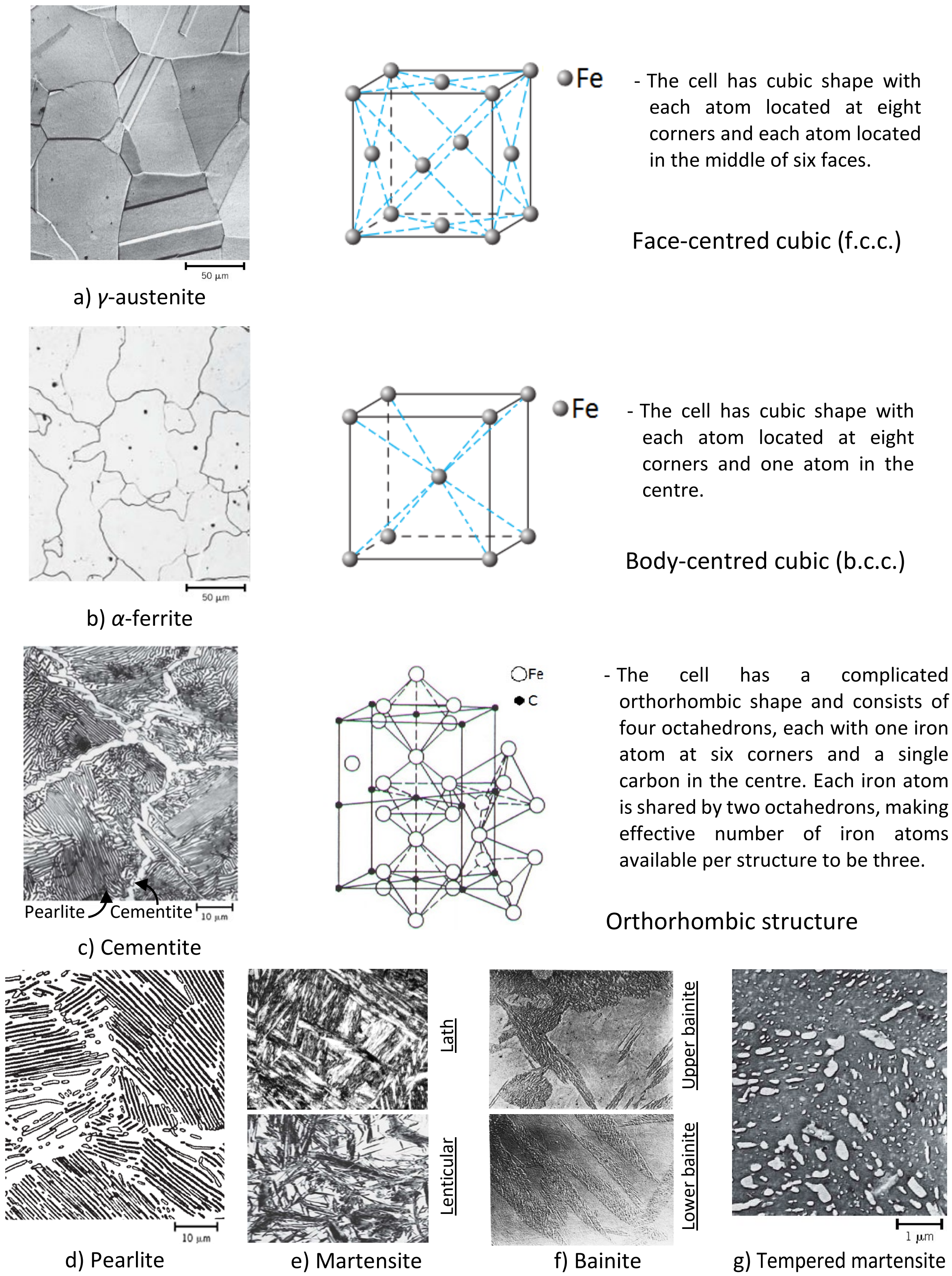


Figure 2.2 Principal crystal types and photomicrographs of microstructures in carbon steels

2.2.2 Iron-carbon phase diagram

All metals naturally exist in crystalline state. The crystallization of steel undergoes a temperature-dependent transformation of crystal structure, called allotropic change. Metallurgically, the plain carbon steel is an interstitial solid solution of carbon (C) atoms acting as the solute in iron (Fe) solvent. A phase is a region throughout that all physical properties of a materials are uniform and separable from others. Various equilibrium phases exist in the iron-carbon phase diagram, with the temperature (°C) plotted vertically, and the carbon content (wt%) plotted horizontally, as shown in Figure 2.3.

According to the carbon content, the following classification of the carbon-iron alloy is also indicated at the bottom of Figure 2.3.

- C% < 0.022% Pure iron
- C% = 0.022~2.14% Carbon steel
- C% = 2.14~6.70% Cast iron

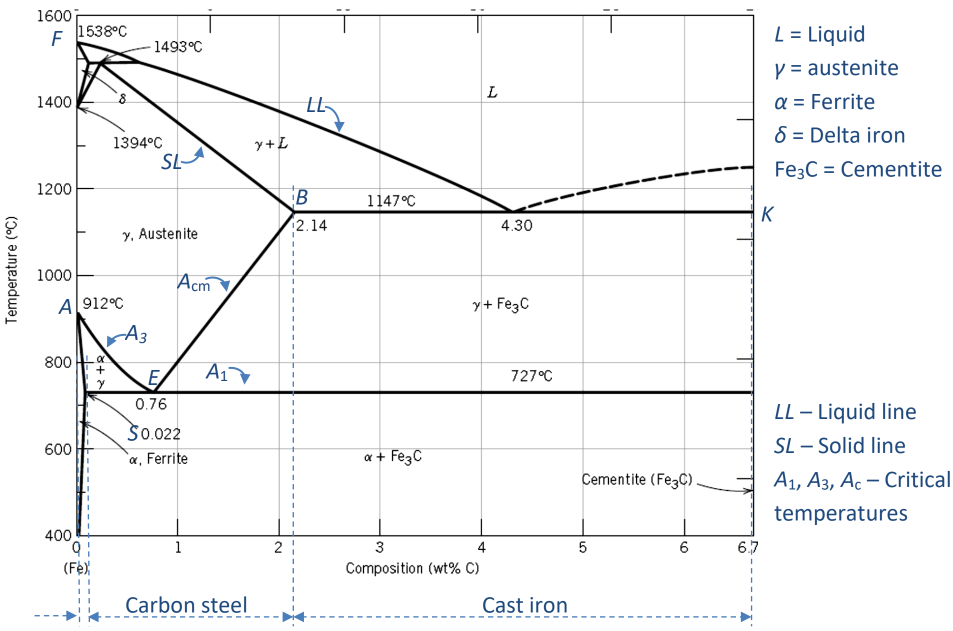


Figure 2.3 Iron-carbon phase diagram

Table 2.2 Critical points in an iron-carbon phase diagram

Point	Temperature (°C)	Carbon content (wt%)	Significations
F	*1538*	*0.000*	**F**reezing point of pure iron
B	*1147*	*2.140*	Maximus solubility of carbon in austenite
A	*912*	*0.000*	**A**llotropic changes
E	*727*	*0.760*	**E**utectoid point that austenite entirely transforms into pearlite
S	*727*	*0.022*	Maximus solubility of carbon in ferrite

When a state or a structure of carbon-iron alloy changes into another, the turning point of the cooling curve is called the critical point in this phase diagram. The curve between two critical points represents the limit line of transformation, and Table 2.2 gives the significations of some critical points relatively to carbon steel

As the temperature falls, the liquid alloy starts to crystallize on liquid line *LL*, where after, the crystallization ends on line *FBK* with completely solid austenite. In the range of A_1 to A_3 or A_1 to A_{cm}, there occurs a reversible equilibrium equation such as:

$$\text{Austenite} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftarrows}} \text{Ferrite + Cementite}$$

The symbols A_1, A_3 and A_{cm} are critical temperatures defined as follows:
A_1 – transition line of austenite and pearlite
A_3 – transition line of austenite and ferrite
A_{cm} – transition line of austenite and cementite

These symbols are often subscripted with 'c' or 'r' to indicate whether it is on heating or on cooling. For example, A_{c1} and A_{c3} denote critical temperatures on heating, and A_{r1} and A_{r3} denote critical temperatures on cooling. The velocity-dependent hysteresis causes the shift up of *A* lines on heating and the shift down on cooling. The faster the heating or cooling rate, the greater the gap is between lines at the same composition point.

2.2.3 Transformation of phases throughout the cooling process

Generally, the carbon content of plain carbon steel in structural engineering is around or below 0.2%. Hypoeutectoid steels have a composition C_0 to the left of a eutectoid point *O*, between 0.022 and 0.76 wt% C. It is feasible to describe the development of microstructures in plain carbon steel during cooling by the phase diagram of hypoeutectoid steel, as shown in Figure 2.4.

In Figure 2.4, the eutectoid point *O* represents the temperature of 727°C and the composition of 0.76 wt% C, that is, where a eutectoid reaction occurs. It is represented by the following equation as well as the formation diagram in Figure 2.4.

$$\gamma \text{ (0.760 wt\% C)} \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftarrows}} \text{pearlite } [\alpha \text{ (0.022 wt\% C)} + Fe_3C \text{ (6.7 wt\% C)}]$$

Along the vertical line *yy'* in Figure 2.4, there are four round diagrams at four points that illustrate the microstructural transformation in slow cooling.

At point *c*, the microstructure consists of entirely austenitic grains above line A_3. When temperature falls into the two-phase region *MNO*, both ferrite and austenitic coexist as in the schematic microstructure of points *d* and *e*. Initially, most ferritic nuclei precipitate along the origin austenitic grain boundaries (point *d*), and then, those small ferritic particles start growing around the shrinking austenite (point *e*). During cooling through this region, just below A_3 but still above A_1, the carbon content in ferrite slightly increases along line *MN* within the ceiling of 0.022 wt% C. Meanwhile, the composition of austenite gets dramatically richer in carbon along line *MO*, up to the eutectoid composition of 0.76 wt% C, due to the separation of ferrite.

When temperature falls just below A_1, all the remaining austenite transforms into pearlite by the eutectoid reaction, and the prior ferrite is reserved as proeutectoid (before eutectoid) ferrite surrounding the pearlite colonies, as shown in the schematic diagram at point *f*. In the formation diagram shown in Figure 2.4, carbon atoms diffuse from ferrite to cementite in the direction indicated by arrows, and the pearlite lamellae extends from the boundary into the grain of parent austenite until the rest austenite is completely consumed. Thus, the formation of pearlite is based on the decomposition of carbon-rich austenite, which momentarily precipitates alternate stringers of cementite and eutectoid ferrite.

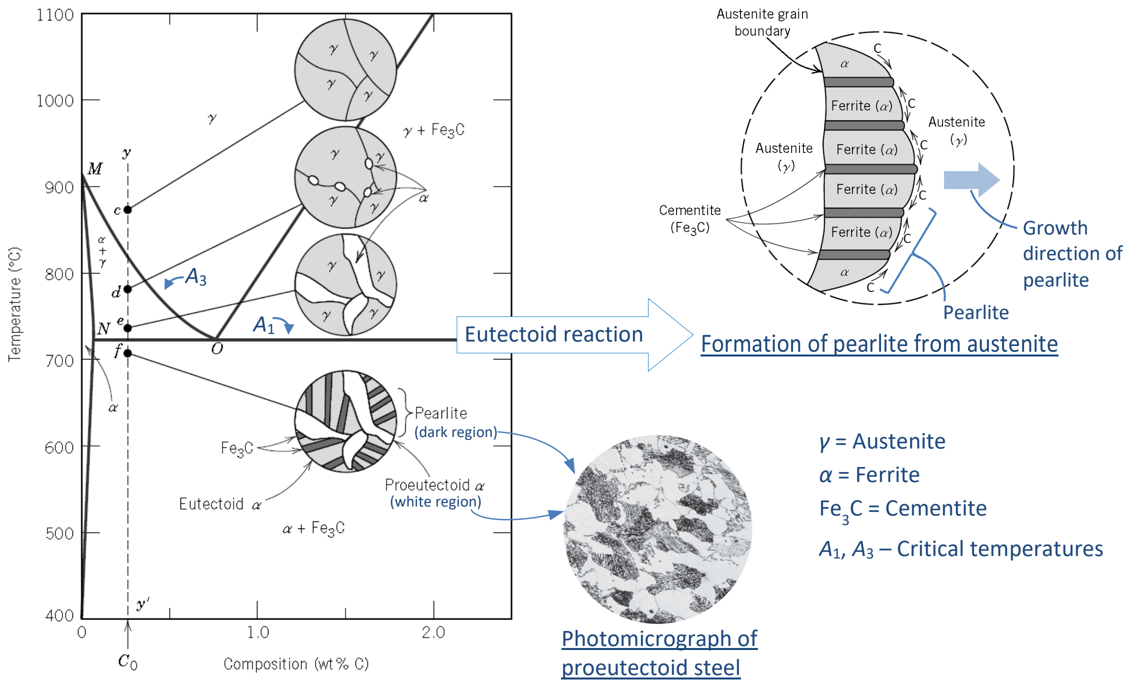


Figure 2.4 Iron-carbon phase diagram of hypoeutectoid steel

2.3 Mechanical Working and Heat Treatments

The mechanical working of steel materials is commonly achieved through rolling which readily increases the yield strengths of the steel materials. This effect is apparent in many materials' specifications, which specify several levels of strength reduction with increasing material thickness. However, while rolling increases the strengths of the steel materials, it also reduces their ductility at the same time.

2.3.1 Types of delivery conditions

The effect of heat treatments is perhaps best explained by reference to the following production processes or rolling regimes that are widely employed in steel manufacturing:

- As-rolled steel AR
- Normalised steel and Normalised-rolled steel: N
- Thermomechanical rolled steel: M or TMCP
- Quenched and tempered steel: Q

As shown in Figure 2.5, it should be noted that:

a) During the manufacture of a steel material, steel cools as it is rolled. The typical rolling finish temperature is 750°C, and such steel is termed "As-rolled" or "AR". However, it is usually necessary to provide some sort of heat treatment during rolling to achieve the required mechanical properties.

b) In general, the process of 'Normalising' is widely adopted in which an as-rolled steel material is heated up to approximately 900°C, and held at that temperature for a specific time, before being allowed to cool naturally. This process refines the grain size and improves the mechanical properties of the steel material, specifically its toughness. It also renders the mechanical properties of the steel material more consistent, and removes residual rolling strains.

   Normalised rolled is a process whereby the rolling finish temperature is above 900°C, and the steel material is allowed to cool naturally. This has a similar effect on the properties as normalising, but it eliminates one process. Normalised and normalized-rolled steel materials are denoted with "N".

c) Thermomechanical rolled steel utilises a different chemistry in the steel material, which permits a rolling finish temperature below 700°C, before the steel material cools naturally. It should be noted that greater force is often required to roll the steel material at these temperatures, and that the mechanical properties are retained unless the steel material is reheated above 650°C. Thermomechanical rolled steel is denoted "M" or "TMCP".

d) The process of quenching and then tempering during the manufacturing of the steel material requires a normalised steel material heated up to 900 °C. The steel material is rapidly cooled or "quenched" to produce steel with high strength and hardness, but low toughness. The toughness is then restored by reheating it to 600°C, maintaining the temperature for a specific time, and then allowing it to cool naturally, or "tempering". Quenched and tempered steel materials are denoted with "Q" or "QT".

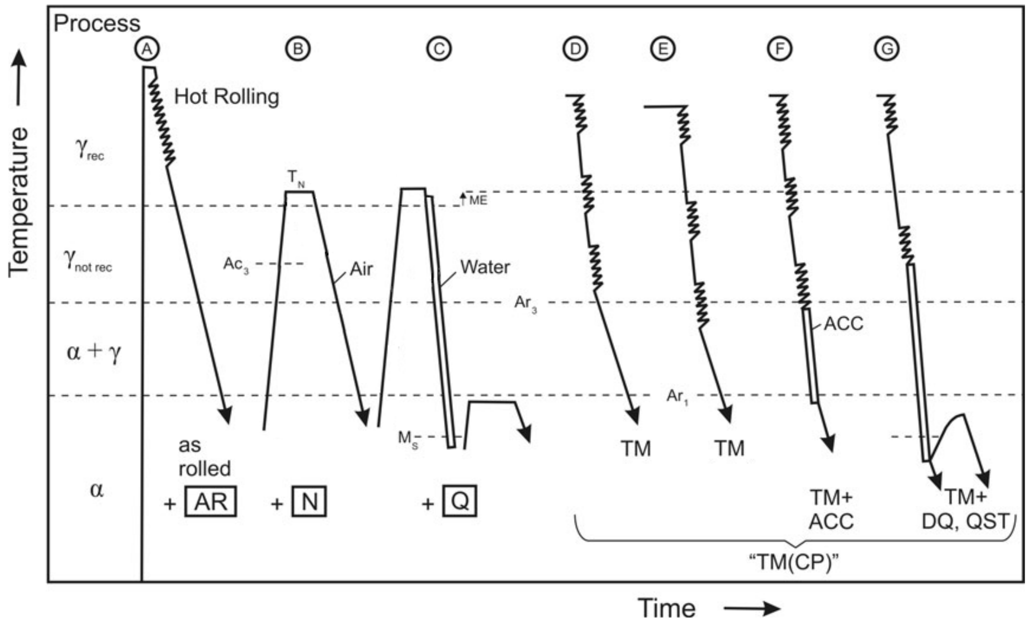


Figure 2.5 Comparison between various delivery conditions

These abbreviations in Figure 2.5 that are not mentioned above can be explained as follows:

γ_{rec} – temperature region for recrystallized austenite

$\gamma_{not\ rec}$ – temperature region for non-recrystallized austenite

$\alpha+\gamma$ – temperature region for coexistence of ferrite and austenite

α – temperature region for coexistence of ferrite and pearlite (or ferrite and bainite or and tempered martensite)

ME – temperature increase for recrystallization due to micro-alloying

T_N – normalizing temperature

ACC – accelerated cooling

DQ – direct quenched

QST – self tempering of quenched material

2.3.2 Metallurgical aspects of rolling and heat-treatments

a) Hot rolling

Rolling is a forming operation of metal, in which metal passes through multiple rollers to produce a sequential reduction and uniformity in thickness. Hot rolling is conducted above the temperature at which recrystallization occurs; otherwise, it's cold rolling.

Semi-finished casting products are large-size steels, such as billets, blooms, and slabs. To obtain required shapes and properties, homogeneously heated as-cast steel is precisely rolled above the recrystallization temperature, then cooled in the static air. This rolling method is regarded as the term "as-rolled condition". It produces AR steel that will be subsequently heat-treated to achieve more specific properties as customer requires.

Above the recrystallization temperature, the microstructure of steel is completely austenite consisting of coarse equiaxed grains. As the material remains relatively soft and ductile in the austenitic state, the large plastic deformation is possible and repeatable. The hot-rolling serves as a process to damage cast microstructure, refine crystal grains, and eliminate defects of the microstructure. The steel organization is compacted and homogenized during the hot rolling. Besides, the external defects formed during pouring, such as bubbles, cracks, and osteoporosis, can be welded together under elevated temperatures and pressures.

However, the hot-rolled steel is no longer isotropic to a certain extent. The improved mechanical properties reflect in the rolling direction. Non-metallic oxides and sulphides result in internal stratification and external scaled appearance. In addition, the deformation and uneven cooling induce residual stresses. Dimensional tolerances vary widely from 2 to 5 % of the overall dimensions due to thermal contraction and warping.

Figure 2.6 shows the change in grain size of the crystalline structure during hot-rolling. The restoration process will be discussed in the following text.

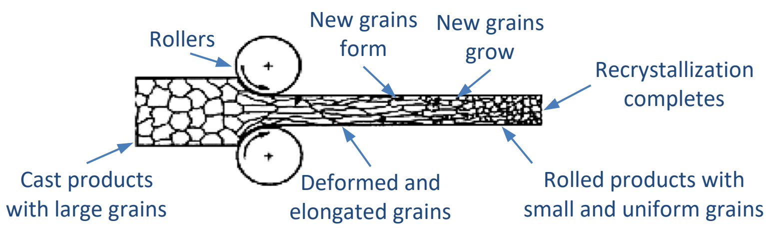


Figure 2.6 Schematic illustration of change in microstructure during hot rolling

b) Normalizing

Normalizing is regarded as the softening process in heat-treatment. AR steel is re-heated about 50°C above the critical temperature A_{c3} (for proeutectoid steel) to restore the crystalline structure in austenitic phase. At elevated temperatures, a recovery phase occurs, and most of the internal residual stresses are relieved by eliminating crystal imperfections and rearranging dislocation configurations. After recovery is finished, recrystallization phase begins to refine the grain structure, and continues to relieve stresses. A new set of strain-free and equiaxed grains nucleates and grows by consuming the original deformed grains, until recrystallization completes. In this phase, the previously stress-hardened steel becomes softer and weaker, yet more ductile. Grain growth is the third phase following recrystallization, in which strain-free grains will continue growing if the steel is held at high temperatures. The average grain size increases with time, and therefore, the heat treatment should be terminated before appreciable grain growth has occurred to ensure the microstructure is fine-grained. The changes of characteristics and microstructure are graphically presented in Figure 2.7.

Recovery, recrystallization, and grain growth are time-dependent and non-instantaneous processes. Also, heating and cooling generate temperature gradients between the outside and the interior portions of the metal piece. Large temperature gradients may lead to warping or even cracking in case that temperature drops rapidly. Thus, the holding time at high temperature must be sufficient to accomplish all necessary transformations, and to achieve a uniform thermal transmission in temperature gradients.

The grain sizes of ferrite and pearlite at room temperature depend on the cooling rate. The grain will be coarser if cooled slowly in furnace, or finer if cooled faster in air. In normalizing process, prior refined austenitic grains and air-cooling produce uniform compositions and finer grains of the ferrite and pearlite structure, resulting in higher strength and hardness together with lower ductility.

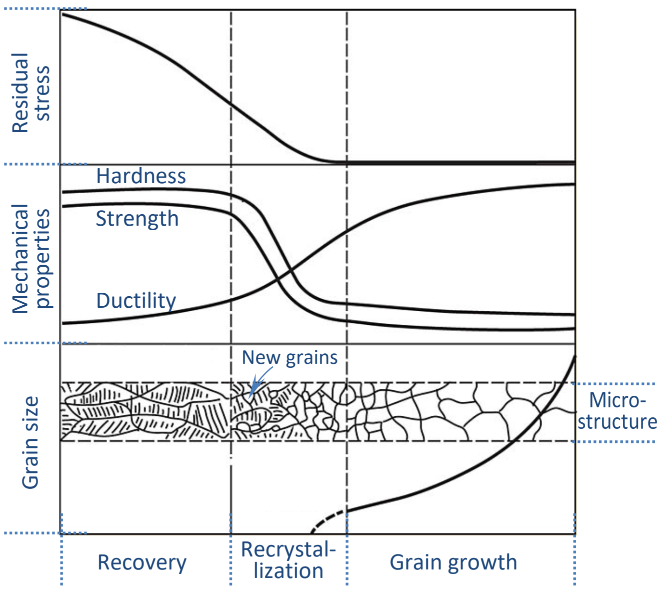


Figure 2.7 Schematic representation of recovery, recrystallization and grain growth

c) Thermomechanical rolling

Thermomechanical rolling involves various combinations of controlled thermal treatments and mechanical deformation processes in order to obtain cost-effective steel products with high strength and toughness.

Suitable micro-alloying elements, like Niobium (Nb), Vanadium (V), and Titanium (Ti), are frequently added in steel to enhance the strength by inducing fine and stable interphase precipitation of carbides and nitrides. This can restrict austenite grain growth or retard austenitic recrystallization, which is useful for controlling the grain size.

Controlled rolling is usually conducted in two or three stages based on the deformation occurrence relative to the phase transformation. Therefore, microstructural changes in steel during rolling processes can be divided into the following groups as depicted in Figure 2.5:

- In high temperature region of recrystallization, coarse austenite grains are refined by repeated deformations to produce recrystallized grains that transform into relatively coarse alpha grains.
- In low temperature region of non-recrystallization, unrecrystallized austenite grains elongate and form interior deformation bands where ferrite nucleates as well as the austenitic grain boundaries to produce finer alpha grains.

- In two-phase temperature region of austenite and ferrite, austenite continues to form deformation bands, and ferrite deforms to produce a substructure. In cooling, austenite transforms into equiaxed alpha grains while the deformed ferrite sub grains are retained.

Deformation bands and ferrite substructures are important features of controlled rolling. The former internally divides the austenite grain into several blocks, producing a much more refined grain structure. The latter causes a significant increase in the yield strength of the steel.

After rolling completes, a subsequent controlled cooling process is applied to suppress the growth of transformed products, and achieve further refinement of grains. The increased cooling rate will retard the decomposition of austenite and form different micro-constituents by superimposed cooling.

Figure 2.5 illustrates three typical cooling conditions in appropriate cooling mediums: air cooling, accelerate cooling and quenching followed by tempering. The corresponding microstructures after cooling are ferrite, pearlite, bainite, and martensite (or tempered martensite), in order of descending temperature of transformation from austenitic phase.

Table 2.3 summarizes the influence of different cooling conditions on formation and morphology of typical phases that lead to wide differences in properties of the steel.

Table 2.3 Typical microstructures of steels and their morphologies in cooling conditions

<table>
<tr><th colspan="2">Cooling condition</th><th>Phase</th><th>Morphology</th><th>Property</th></tr>
<tr><td rowspan="2">Slow cooling</td><td>Equilibrium cooling (in furnace)</td><td rowspan="2">Pearlite and ferrite</td><td>Nearly equiaxed ferrite of coarse grains and pearlite lamellae</td><td rowspan="5">Softer / Weaker
More ductile
Less tough
↕
Harder / Stronger
Less ductile
Tougher</td></tr>
<tr><td>faster than Equilibrium cooling (in air)</td><td>Finer feathery ferrite grains and denser pearlite lamellae</td></tr>
<tr><td rowspan="2">Medium cooling</td><td rowspan="2">Initial accelerated cooling (in water) then slower cooling (in air) or isothermal cooling</td><td>Upper bainite and ferrite</td><td>Feathery ferrite plates with fine carbide precipitation predominantly on the boundaries</td></tr>
<tr><td>Lower bainite and ferrite</td><td>Acicular ferrite plates with fine carbide precipitation all over the plates at random</td></tr>
<tr><td>Fast cooling</td><td>Very fast cooling (in oil or water) to avoid intruding into other formation areas (e.g. pearlite or bainite), followed by tempering</td><td>Tempered martensite and ferrite</td><td>Process G of Figure 2.5 shows TM-rolling followed by direct quenching and self-tempering. While the outer layer of the material is quenched, the interior stays warmer to subsequently give a tempering by the quenched material itself.</td></tr>
</table>

With the assistance of time-temperature-transformation curve diagrams and continuous-cooling-transformation curve diagrams of steel, various thermomechanical controlled processing “TM(CP)” are developed to obtain special properties by inducing morphological improvement in the microstructure of steel, especially for thick steel plates and high-strength-low-alloy steel.

d) Quenching and tempering

Quenching and tempering are regarded as the hardening process in heat treatment. In quenching, a work piece is re-heated above the critical temperature A_{c3} in order to transform the soft initial structure into full austenite. It is then cooled rapidly by soaking into the quenching medium, such as water or oil, to make transformation occur only in martensitic temperature range. To decide the appropriate cooling rate for producing martensite as much as possible, there are many factors including the characteristics of the quenching medium, the size and geometry of the steel piece, and the alloy composition.

A martensitic structure produced after quenching is hard and brittle with high residual stresses. To prevent cracking and distortion, tempering should be carried out immediately to relieve internal residual stresses. The quenched steel is reheated over the temperature M_s at which martensite starts to form, but below the eutectoid temperature A_{c1} to avoid phase transformation. The temperature range is normally between 250°C ~ 650°C. At elevated temperatures, carbon atoms migrate out of the highly strained martensitic lattice to form iron carbide precipitating in the ferrite matrix. Internal stresses get released by carbon diffusion. A specific holding time before cooling is necessary as the microstructure changes slowly. After tempering, the single-phase martensite transforms into the tempered martensite composed of the stable cementite and ferrite. The fine and uniform cementite particles result in the high strength and hardness as martensite, and the continuous ferrite matrix improves ductility and toughness.

2.4 Chemical Composition

In general, the chemical composition is the most important factor affecting the mechanical properties of steel materials. Adding chemical elements such as Carbon, Manganese, Niobium and Vanadium either during tapping or secondary steel making will increase the strengths of the steel materials. However, these additions not only add to the cost of the steel materials, but also adversely affect other mechanical properties such as ductility, toughness, and weldability. For example, the Sulphur level should be kept low for good ductility while toughness may be readily improved with the addition of Nickel. Consequently, the chemical composition for each steel material has to be carefully considered to achieve the required properties.

2.4.1 Effects on mechanical and material performance

The effects of some commonly used chemical elements on the mechanical and material performance of steel materials are summarized in Table 2.4 while their effects on the properties of hot-rolled and heat-treated carbon and alloy steels are described as follows:

a) Iron (Fe)

Iron is the single most important element in a steel material, comprising roughly 95% of the steel material. Any steel material with a percentage of iron lower than 95% will not be classified as "structural".

b) Carbon (C)

Carbon is the second most important chemical element in the steel material. It is commonly regarded as the principal strengthening (hardening) element where each additional increment increases hardness as well as both yield and tensile strengths of the steel material. However, increased amounts of carbon cause a decrease in ductility, toughness and weldability. Typical Carbon contents in modern steel materials range from 0.05 to 0.25 %.

c) Manganese (Mn)

An important element, Manganese also increases strength and hardness of the steel material, but to a lesser degree than Carbon. Increasing the Manganese content also decreases ductility and weldability, but again, to a lesser extent than Carbon. Manganese has a strong effect on the hardenability of the steel material, and is beneficial to surface quality. Typical Manganese contents in modern steel materials range from 0.50 to 1.70 %.

It should be noted that Manganese combines with sulphur to form manganese sulphides which are globular, non-metallic inclusions in the matrix of the steel material, thus minimizing the harmful effects of sulphur. The amount of such inclusions and the degree to which they have been deformed during the hot-rolling process have significant effects on the through-thickness properties of steel. This also affects the welded fabrication of steel sections.

d) Sulphur (S)

Sulphur has detrimental effects on strength, transverse ductility, toughness as well as the weldability of steel materials. It also promotes segregation in the matrix of the steel material. For these reasons, it is generally considered an undesirable element, and the content of Sulphur is thus restricted to no more than 0.04 to 0.05 %. It should be noted that current continuous cast steel sections, which are often silicon-killed, generally have an actual sulphur content of around 0.02 to 0.03 %, and this is well within the specification limits.

It is generally considered that through-thickness (TT) properties for ingot-based products can be improved by lowering the Sulphide content. This is because through-thickness strength and ductility are tied to non-metallic inclusions in the form of Manganese Sulphides (MnS). Hence, lowering the magnitude and number of such inclusions improves the TT response of the steel material. For lamellar tearing resistant plate steels, the maximum sulphur content is typically found to be 0.01 %.

e) Phosphorus (P)

As for Sulphur, Phosphorus promotes segregation in the matrix of the steel material. Increasing the Phosphorus contents increases strength and hardness, but reduces ductility and toughness in the as-rolled condition. Such a reduction in ductility and toughness is found to be more pronounced in quenched and tempered high cabon steel materials.

f) Chromium (Cr)

Chromium is primarily used to increase the corrosion resistance of a steel material. It also increases hardenability, strengths at high temperatures and improves abrasion resistance. Different types of weathering steel have various Chromium contents ranging from 0.1 to 0.9 %.

g) Copper (Cu)

Copper is the other primary corrosion-resistant element used in a steel material. It is typically at not less than 0.2 % for steel materials manufactured with the use of an electric arc furnace (EAF), and about 0.02 to 0.03 % for steel materials manufactured with the use of a basic oxygen furnace (BOF).

h) Silicon (Si)

Silicon is one of the two most important steel material de-oxidizers, and this means that it is very effective in removing oxygen from the steel material during the pouring and solidification process. Typical Silicon content of a steel material is less than 0.4 %, but it must be at least 0.1 % if the steel material is to be considered fully killed. The removal of Oxygen to the point that Carbon Monoxide (CO) does not develop during solidification is referred to as a ‘killing’ condition, and this leads to the use of those terms such as ‘killed’ or ‘semi-killed’ steel materials. Steel materials produced with little or no oxygen removal are called rimmed or cawed steels. It should be noted that killed steels generally have a more uniform, finer grained crystalline structure, and hence, their strength, ductility and toughness are significantly better than those of the semi-killed and rimmed steels.

Because of the nature of this form of steel production, ingot-based steel products are generally classified as killed, semi-killed or rimmed steel materials. In the past, most small and medium-size rolled sections were delivered as rimmed sections, unless the purchaser specifically ordered semi-killed or killed rolled sections. Nowadays, production of sections in many steel mills is entirely based on continuous casting, and hence, all of these sections are fully killed due to the nature of the process. It should be noted that while Silicon is the primary killing agent for sections, both Aluminium and Silicon are used for plates.

i) Aluminium (Al)

Aluminium is the other primary killing agent for steel materials, and it is sometimes used in combination with Silicon. In modern steel mills, Aluminium is used in plates for grain refinement.

j) Columbium (Cb)

Columbium which is also referred to as Niobium (Nb) is used to enhance the strength of a steel material, and is one of the key elements in the various high strength low alloys steel materials. It has effects similar to those of Manganese and Vanadium, and is often used in combination with Vanadium. Due to weldability requirements, Columbium is used in an amount less than 0.05 % in high strength steel materials.

k) Molybdenum (Mo)

Molybdenum has effects similar to those of Manganese and Vanadium, and is often used in combination with one or the other. This element increases readily the strength of the steel material at elevated temperatures as well as the corrosion resistance.

l) Nickel (Ni)

Nickel is a powerful anti-corrosion agent, and it is also one of the most important elements in improving toughness of a steel material. In combination with Chromium, Nickel improves hardenability, impact strength, and fatigue resistance of the steel material. The Nickel contents generally vary between 0.25 and 1.5%.

m) Vanadium (V)

Vanadium has effects similar to those of Manganese, Columbium and Molybdenum. In particular, it aids in the development of a tough, fine-grained steel structure. Vanadium is an important alloying element in HSLA steel materials.

n) Boron (B)

Boron is useful as an alloying element in the steel because of its effect on hardenability enhancement. Boron is added to unalloyed and low alloyed steels to enhance the hardness level through enhancement hardenability. Boron added to high-speed-cut steels could enhance their cutting performance, but would reduce their forging qualities.
Addition of boron in quantities of up to 0.01% to austenitic steels also improves their high-temperature strength. Boron steels are used as high-quality, heat-treatable constructional steels, steels for carburization and cold forming steels such as steels for screws. However,

high Boron content would lead to a risk of hydrogen induced cold cracking following welding. Thus, it is important to monitor the Boron content during tapping and the steel making process.

Other chemical elements: Some of the structural steels, especially the HSLA-types, use small amounts of elements such as Boron (B) and Titanium (Ti). Boron enhances strength; it also improves the hardenability of quenched and tempered structural steels. Titanium improves toughness. Nitrogen (N) will be present as well; in combination with some elements, it enhances the strength of the steel material. However, free nitrogen is an important factor in the strain aging that may occur in certain steel materials under certain conditions; this is not considered a critical issue for structural steel materials.

It should be noted that due to the changes in steelmaking practice over the past decade, the use of scrap as a source for the furnaces, so-called residual elements (or simply residuals) may play a role in the development of steel materials with desirable properties.

Table 2.4 Typical functions of chemical elements in structural carbon steels

Elements	Typical content (%)	Strength	Ductility	Toughness	Hardness	Weldability	Corrosion resistance	Remarks
Aluminum (Al)	*0 ~ 0.015*	↑	-	↑	-	-	-	
Boron (B)	*0 ~ 0.005*	-	-	-	↑	-	-	Uses only in aluminium-killed steels, and most effective in low carbon steel.
Calcium (Ca)	*0 ~ 0.015*	↑	-	↑	-	↑	-	▪ Minimizes re-heat cracking ▪ Prevents lamellar tearing in large restrained welded structures
Carbon (C)	*0.05 ~ 0.25*	↑	↓	↓	↑	↓	-	Moderate tendency to segregate
Chromium (Cr)	*0.10 ~ 0.90*	↑	-	-	↑	-	↑	
Copper (Cu)	*0.20 ~ 0.60*	-	-	-	-	-	↑	
Manganese (Mn)	*0.50 ~ 1.70*	↑	↓	-	↑	↓	-	Controls harmful effect of Sulphur
Molybdenum (Mo)	*< 0.30*	↑	-	-	-	-	↑	Increases the yield strength at elevated temperatures, as well as the creep strength.
Columbium (Nb/Cb)	*< 0.05*	↑	-	↑	-	-	-	Columbium (Cb) referred to as niobium (Nb) in Europe is one of the key elements in the various HSLA grades.
Nitrogen (N)	*0 ~ 0.004*	↑	↓	↓	↑	-	-	
Nickel (Ni)	*0.25 ~ 1.50*	↑	-	↑	-	-	↑	
Phosphorus (P)	*< 0.05*	↑	↓	↓	↑	↓	-	
Sulphur (S)	*< 0.05*	↓	↓	↓	-	↓	-	
Silicon (Si)	*0.10 ~ 0.40*	-	-	-	-	-	-	Good deoxidizers of steel
Titanium (Ti)		↑	-	↑	↑	-	-	Increases creep and rupture strength
Vanadium (V)	*< 0.20*	↑	-	↑	-	-	-	

2.4.2 Effects on weldability

It is essential that a steel material has a chemical composition that promotes fusion of the base metal and the weld electrode (filler) metal, without the formation of cracks and similar imperfections during welding. This characteristic is referred to as the weldability of the steel material. In general, all currently available steel materials are weldable although the requirements for some high strength steel materials are considerably more restrictive than those for normal strength steel materials.

The most common measure of weldability is the carbon equivalent value, CEV, which is used to assess the combined effect of carbon and the other chemical elements on the cracking susceptibility of the steel materials. Based on testing of the steel materials within certain ranges of chemical compositions, various empirical formulas for determination of the CEV of steel materials are available:

$$CEV = C + (Mn + Si) / 6 + (Cr + Mo + Cb + V) / 5 + (Ni + Cu) / 15 \qquad \text{(Eq. A)}$$

$$= C + Mn / 6 + (Cr + Mo + V) / 5 + (Ni + Cu) / 15 \qquad \text{(Eq. B)}$$

$$= C + Si / 30 + (Mn + CU + Cr) / 20 + Ni / 60 + Mo / 15 + V / 10 + 5B \qquad \text{(Eq. C)}$$

The numbers that are entered are the chemical element contents in percent. It should be noted that:

a) For the CEV from Eq. A, weldability is deemed acceptable if the CEV is less than approximately 0.50.

b) Eq. B is probably the most commonly used, and it is the formula proposed by the International Institute of Welding (IIW). A carbon equivalent based on Eq. B is known to be a good measure of the hardenability of the steel, and the weldability is good if the CEV is less than 0.43 for most commonly adopted structural steelwork.

c) The CEV from Eq. C is commonly referred to as P_{cm}, the composition parameter. It is a carbon equivalent formula that was developed on the basis of a large number of tests of the cracking susceptibility of HSLA steels. The acceptability level for the CEV from Eq. C is approximately 0.23.

It should be noted that Eq. B is referred to in subsequent sections of this document. A number of manual, semi-automatic and automatic welding processes are currently available. Certain types are generally preferred for structural shop welding, while others are preferred for field welding. The American Welding Society's (AWS) "Welding Handbook" offers detailed descriptions of all such processes, along with their advantages and disadvantages.

2.5 Basic Material Properties of Steel Materials

The basic material properties of steel materials are:

Modulus of elasticity,	E	$= 210.0\ kN/mm^2$
Shear modulus,	G	$= 80.0\ kN/mm^2$
Poisson's ratio,	ν	$= 0.3$
Coefficient of linear thermal expansion		$= 12 \times 10^{-6}\ /\ ^{o}C$

2.6 Designation of Steel Grades

The designation of steel grades is defined in the product standard for hot rolled products and structural steels in EN 10027-1, and the classification of steel grades is based on the minimum specified yield strength at ambient temperature together with various parameters for other mechanical properties and delivery conditions as follows:

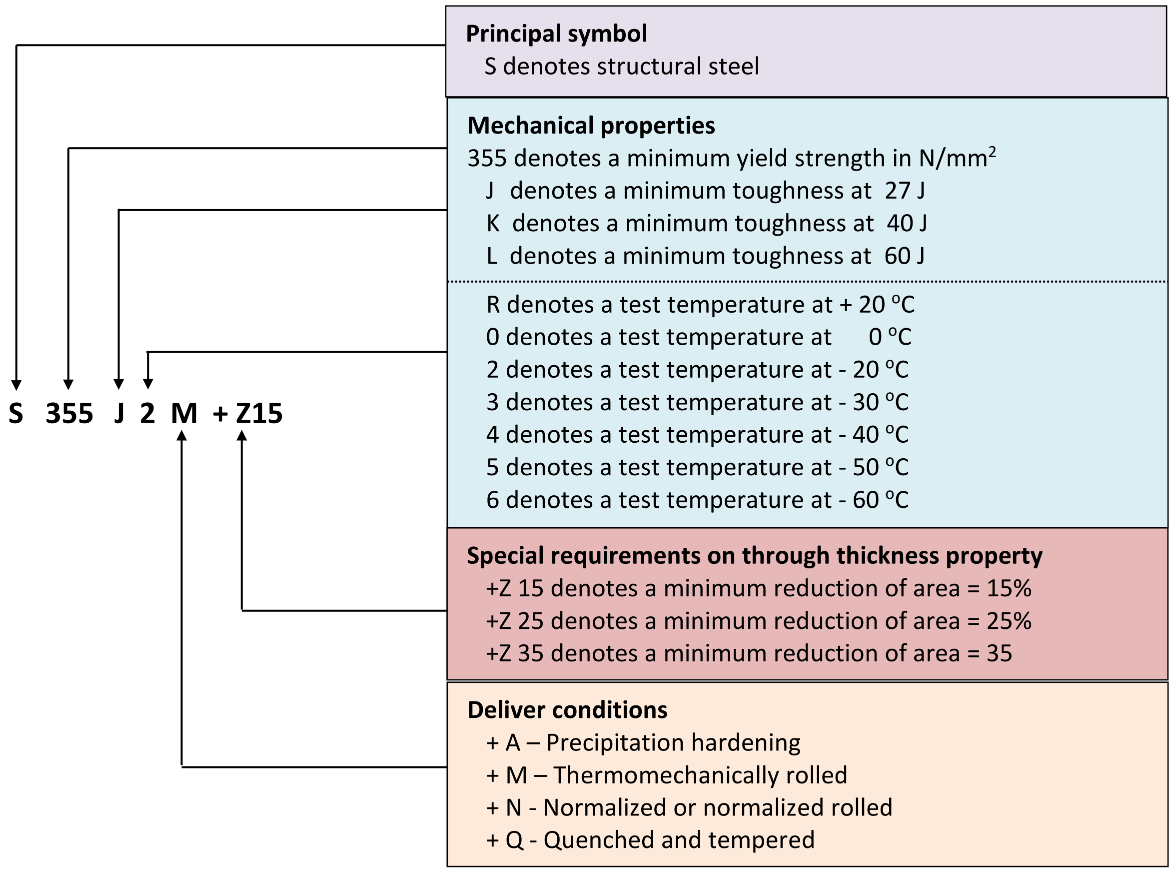


Figure 2.8 Designation of steel grade according to EN 10027-1

For guidance on the choice of through-thickness properties, refer to EN 1993-1-10.

Section 3 Equivalence of Steel Materials and Their Selection

In this Chapter, a number of general criteria which influence the use of steel materials are presented together with basic considerations on the use of various steel product forms. The overall selection considerations for design and construction engineers are also described.

As the main theme of this Chapter is equivalence of steel materials, the essential requirements for establishing equivalent steel materials to European steel materials specifications are fully described. Material performance requirements given in various parts of EN 10025, EN 10149, EN 10210 and EN 10219 as well as other sources are summarized in a tabulated format, and these are presented systematically in Tables MR 1 to 11 for easy reference. Quality assurance requirements recommended in various European steel materials specifications are also briefly presented, and key features of a Factory Production Control system given in Appendix B.4 of EN 10025-1 is described.

3.1 Criteria Influencing Use of Steel Materials

In a steel structure, the steel materials are primarily subject to axial (tensile and compressive) forces, shear forces and bending moments. They respond linearly to applied stresses up to a 'yield point', and thereafter exhibit a significant capacity for plastic straining after first yield. Alternatively, especially for high strength steel materials, they respond non-linearly to applied stresses, and the proof strength is considered to be achieved when a 'proof strain' at 0.2 % is attained. At large deformations, i.e., strains larger than 2 %, post-yielding strengths are significantly larger than yield strengths because of the effect of strain hardening, up to tensile strengths, typically, 15 to 25% in excess of the yield values. The steel materials fracture eventually at a typical elongation with a strain limit of 15 to 25%. It should be noted that this mechanical behaviour is fully utilised to advantage in structural steelwork through rational design for structural adequacy and economy.

3.1.1 Basic considerations

Steel materials are supplied in two product forms:

i) flat products including
   - steel plates with thicknesses larger than 3.0 mm and up to 150 mm, and
   - steel strips with thicknesses smaller than or equal to 3.0 mm,

and

ii) long products including
   - hot rolled sections such as universal beams, universal columns, joists, channels, angles and tees,
   - hot rolled or cold formed bearing piles,
   - hot finished hollow sections such as rectangular, square and circular hollow sections, and
   - cold formed hollow sections.

For structural applications, these products are inevitably cut to size and shape, and components are connected to one another through either bolts or welding in fabrication shops or on site.

The basic requirement in the choice of a particular steel material is that it should be fit for the intended application and the design conditions required. The mechanical properties of particular importance to a steel designer include:

- strength,
- ductility,
- toughness,
- through thickness properties,
- weldability, and
- strength, stiffness and thermal expansion at elevated temperatures.

In addition, the steel materials should have a required service life which suits the expected environmental conditions, and hence, corrosion resistance is also important.

Where the steel material is to be fabricated into components or structures, its ability to retain the required properties during fabrication should be clearly established. One of the most important factors is the weldability of the steel material, and in this respect, the chemical composition of the steel material should be controlled within tight limits, and the welding processes and procedures adopted should be compatible with the steel material chosen.

In practice, both corrosion resistance and fire resistance of the steel material may be important factors in some structural applications. A clear decision has to be taken at the design stage as to whether corrosion resistance and fire resistance are to be achieved through the use of additional protection systems, or inherently through the chemical composition of the steel material itself.

Increased strength of steels can be obtained using various processes, including an increased alloying content, mechanical rolling and heat treatment, or cold working. In general, as the strength increases so does the cost, and there may be little advantage in using high strength steel materials in situations where either fatigue or buckling are likely to be the critical modes of failure.

Certain product forms are available only in certain types and grades of steel materials. It may not be possible to use high strength steel materials for some product shapes and retain their dimensional tolerances through the various stages of heat treatments when distortion becomes significant.

3.1.2 Overall selection considerations

Among various discussions on chemical composition, mechanical working and heat treatments of steel materials as well as key issues of structural design and fabrication, the following considerations are recommended when selecting steel materials for a particular structure:

i) Type of structure, structural form, supporting conditions
ii) Loading requirements, service conditions, dynamic or cyclic loads
iii) Material strength, ductility, toughness, through thickness properties, weldability, and chemical composition
iv) Service environment, atmospheric corrosion and fire protection
v) Structural member types, sizes and lengths as well as connection methods: welded or bolted connections
vi) Connection configurations between members: beam-to-column connections, beam-to-beam connections, compression and tension splices
vii) Fabrication methods, including joining techniques, cutting, grinding, shop welding, and site welding
viii) Construction sequence and requirements, including site welding
ix) Qualifications and experience of design, fabrication and construction personnel
x) Equipment required for shop fabrication and site erection
xi) Inspection methods and the qualifications and Quality Assurance procedures of the inspection personnel
xii) Special considerations:
    - complicated connections with heavy bolted and welded connections;
    - large weldment in a tri-axial state of stress, strain and restraint;
    - weld contraction restraint and associated deformations;
    - directionality of material properties;
    - occurrence and consequences of cracks during (a) fabrication, (b) erection, and (c) service;
    - fatigue details, crack initiation and propagation;
    - brittle fracture conditions; and
    - corrosion and stress corrosion.

Although there are many material requirements and tests that may be conducted, many of them are only applicable to certain types of structures. For example, a bridge structure, which is exposed to the natural environment and subject to high cycle fatigue conditions, needs to have steel materials with toughness properties that are commensurate with the anticipated service conditions. Clearly, it will be neither realistic nor economical to specify similar criteria for a statically loaded, enclosed building structure.

3.2 Equivalence of Steel Materials

In the 2000s, owing to large fluctuations in the costs of steel materials in the global markets, Chinese steel materials became practical alternatives to British steel materials on a number of construction projects in Asia, in particular, in Hong Kong, Macau and Singapore. During the drafting of the "Code of Practice for the Structural Use of Steel" for the Buildings Department of the Government of Hong Kong SAR from February 2003 to August 2005, it was decided necessary to devise a means to allow, or more accurately, to formalize, the use of Chinese steel materials as equivalent steel materials for structures which were originally designed to BS5950. Various parts of Chapter 3 of the Hong Kong Steel Code does provide basic principles and considerations for qualifying, as well as accepting, steel materials manufactured to the following national materials specifications:

- American standards,
- Japanese standards,
- Australian / New Zealand standards,
- Chinese standards, and
- Russian standards.

A simple and practical classification system for non-British steel materials is also included in the Hong Kong Steel Code by which the design strengths of these steel materials depend on the adequacy of materials specifications as well as effectiveness of the quality control procedures followed during their production.

A similar use of non-British steel materials was also formally adopted in Singapore with the issue of a technical guide entitled "Design Guide on Use of Alternative Steel Materials to BS5950" in 2008, and then its revised version entitled "Design Guide on Use of Alternative Structural Steel to BS5950 and Eurocode 3" in 2012 by the Building and Construction Authority of the Ministry of National Development. These Design Guides aim to provide technical guidelines and design information on the use of non-British steel materials, and the classification system for various steel materials given in the Hong Kong Steel Code was adopted after minor modification. Under the provisions of these Design Guides, alternative steel materials, not manufactured to European steel materials specifications, may be allowed in structural design based on the Structural Eurocodes for construction projects in Singapore.

It should be noted that the following product forms are covered:

1) Structural steels
    - plates
    - sections
    - hollow sections
    - sheet piles
    - solid bars
    - strips for cold formed open sections

2) Thin gauge strips
   - strips for cold formed profiled sheetings

3) Connection materials
   - stud connectors
   - non-preloaded bolted assemblies
   - preloaded bolted assemblies
   - welding consumables

3.2.1 Selection principles

Based on the experiences of the construction industry in Hong Kong and Singapore over the past 30 years as well as the use of both the "Code of Practice for the Structural Use of Steel" in Hong Kong and the "Design Guide on Use of Alternative Structural Steel to BS5950 and Eurocode 3" in Singapore over the past 8 to 10 years, the selection principles for equivalence of steel materials have been established. Both minimum acceptable standards of material performance and quality assurance are considered to be essential requirements for steel materials to be accepted as 'equivalent". After due consideration, key selection principles have been identified as follows:

- Material performance
  a) mechanical strengths for structural adequacy,
  b) ductility for sustained resistances at large deformations,
  c) toughness in terms of energy absorption against impact, and
  d) chemical compositions and weldability for minimized risks of crack formation in welds.

  Thus, it is essential for the manufacturer of any proposed equivalent steel material to demonstrate full compliance with the material performance requirements on dimensional accuracy, mechanical properties, and chemical composition during the manufacturing processes to ensure the material adequacy for use in structural design according to EN 1993 and EN 1994.

- Quality assurance systems
  a) demonstrated compliance with acceptable reference standards,
  b) demonstrated compliance with material tests with sufficient sampling on both chemical composition and mechanical properties, and
  c) effective implementation of certificated quality assurance systems.

  It is also essential for the manufacturer of any proposed equivalent steel material to demonstrate full compliance with the quality assurance requirements during the manufacturing process to ensure its adequacy for use in structural design according to EN 1993 and EN 1994.

In order to demonstrate compliance with the material performance and the quality assurance requirements to European steel materials specifications, intensive routine testing should be conducted according to the relevant materials specifications whilst the manufacturing process should be demonstrated as operating effectively under a Certified

Quality Assurance System. A good example is a Certified Factory Production Control system to Appendix B.4 of EN 10025-1 which should have been effectively implemented, successfully certified and regularly monitored by an independent qualified Certification Body.
When performing rational selection of equivalent steel materials, the following considerations on mechanical properties and chemical composition should be taken account of:

a) Material strengths for structural adequacy

Both the minimum yield strength, R_{eh} , and the ultimate tensile strength, R_m , of the proposed steel materials should be directly adopted from their national materials specifications. It should be noted that the values of these two strength parameters depend heavily on both the dimensions of the coupons and the testing procedures. According to most European steel materials specifications, the values of both the minimum yield and the ultimate tensile strengths are gradually reduced when the plate thickness increases.

Owing to the different systems of strength grades used by various national materials specifications, the values of both the minimum yield and the ultimate tensile strengths are often different to those of the corresponding European steel materials specifications. In these cases, re-design of structural steelwork is necessary.

b) Ductility for sustained resistances at large deformations:

Ductility of steel materials correlates approximately with their elongation limits, that is, the elongations of steel coupons at fracture in standard coupon tests. The values of the elongation limits depend heavily on the dimensions of the steel coupons and the testing procedures as well as the product forms of the proposed steel materials and the steel coupon sampling methods.

If a proposed steel material does not possess sufficient ductility as required by the relevant steel design codes, then the proposed steel material will not be accepted as an equivalent steel material.

c) Toughness in terms of energy absorption against impact

Toughness is an important mechanical property of steel materials, which is the resistance against brittle fracture, and is quantified as the amount of dissipated energy obtained from standard Charpy V-notch impact tests at various design temperatures. In general, if a proposed steel material does not possess sufficient toughness as required in the relevant European steel materials specifications, then the proposed steel material will not be accepted as an equivalent steel material.

Nevertheless, the threshold values of this quantity are found to be related to both the stress levels and the thicknesses of the steel plates, and hence, these values are readily reduced for actual applications of the steel materials using codified rules. In general, these values are often reduced significantly when thin plates are used, and in these circumstances, the steel materials are likely to be considered acceptable.

d) Chemical compositions and weldability to minimize risks of crack formation in welds

As discussed in Chapter 2, the contents of a number of chemicals should be kept to an optimal limit, such as Carbon, Sulphur and Phosphorus as their presence tend to reduce ductility, toughness and weldability as well as promote segregation at the same time. As a simple rule for hot-rolled structural steel sections, the maximum Carbon content should not exceed 0.25 % while the maximum Sulphur content should not exceed 0.05 %. Moreover, the maximum Phosphorus content should not exceed 0.05 %, which is further limited to 0.01 % when a through thickness quality, i.e. Z quality, is specified.

The weldability of steel materials depends on the carbon equivalent value, CEV, which represents the combined effects of Carbon and other chemical elements on the cracking susceptibility of the steel materials.

Hence, if any one of the contents of these non-beneficial chemicals present in a proposed steel material exceeds the corresponding limit given in the relevant European materials specifications, then the proposed steel material will not be automatically accepted as an equivalent steel material. Moreover, if the CEV value of the proposed steel material exceeds the corresponding limit, then, the proposed steel material should be used with caution. Details of the welding procedures, such as interpass temperatures, should be modified according to the thicknesses of the steel materials. Furthermore, welding consumables shall match the steel types, otherwise, testing for non-qualifying welding consumables should be undertaken.

3.2.2 Classification of Steel Materials

Given a satisfactory demonstration of both the material performance and the quality assurance during their manufacturing processes, steel materials with yield strengths from 235 to 690 N/mm^2 are classified as follows:

- **Class E1 Steel Materials**

Steel materials which are

i) manufactured in accordance with one of the **Acceptable Materials Specifications** listed in Appendix A with a fully demonstrated compliance on their material performance, and

ii) manufactured in accordance with an **Acceptable Quality Assurance System** with a fully demonstration of its effective implementation.

Thus, compliance with all the material requirements has been demonstrated through **intensive routine testing** conducted during the effective implementation of a certificated **Factory Production Control** system according to European steel materials specifications. The Factory Production Control System should be certified by an independent qualified certification body.

- **Class E2 Steel Materials**

Steel materials which are

i) manufactured in accordance with one of the **Acceptable Materials Specifications** listed in Appendix A with a fully demonstrated compliance on their material performance, and

ii) manufactured in accordance with an effectively implemented quality assurance system which is different to a Factory Production Control System.

Thus, the steel materials are manufactured in accordance with all the material requirements given in one of the Acceptable Materials Specifications, but without a certified Factory Production Control System in accordance with European steel materials specifications. In general, many steel manufacturers will have already established a form of quality assurance during the manufacturing processes, however, a high level of consistency in the material performance of the steel materials required in European steel materials specifications cannot be verified in the absence of a certified Factory Production Control System. Hence, a demonstration of the conformity of the steel materials is required, additional material tests with sufficient sampling should be conducted for various batches of supply to demonstrate full compliance with both the material performance and the quality assurance requirements. Refer to Section 3.2.3 for details of additional materials tests.

- **Class E3 Steel Materials**

Steel materials for which it cannot be demonstrated they were

i) manufactured in accordance with any of the **Acceptable Materials Specifications** listed in Appendix A; nor

ii) manufactured in accordance with an **Acceptable Quality Assurance System**.

Hence, any steel material which cannot be demonstrated to be either Class E1 Steel Material or Class E2 Steel Material will be classified as Class E3 Steel Material, and the nominal value of yield strength of the steel material is limited to 170 N/mm^2 for structural design; no additional material test is needed in general. However, the design yield strength of the steel material may be increased if additional material tests with sufficient sampling have been conducted for various batches of supply before use.

Table 3.1 summarizes the classification system applying to the various classes of steel materials. It should be noted that a newly defined factor, namely, the material class factor, γ_{MC} , is adopted as a result of the classification, and hence, the nominal values of the yield strength and of the ultimate tensile strength of the equivalent steel materials are given as follows:

- Nominal value of yield strength

$$f_y = R_{eH} / \gamma_{MC} \qquad \text{(Equation 3.1)}$$

- Nominal value of ultimate tensile strength

$$f_u = R_m / \gamma_{MC} \qquad \text{(Equation 3.2)}$$

where R_{eH} is the minimum yield strength to product standards;
R_m is the ultimate tensile strength to product standards; and
γ_{MC} is the material class factor given in Table 3.1.

It should be noted that

a) Plastic analysis and design is permitted for Classes E1 and E2 Steel Materials assuming yield strengths not larger than 460 N/mm^2.

b) For Classes E1 and E2 Steel Materials with yield strengths larger than 460 N/mm^2 but smaller than or equal to 690 N/mm^2, design rules given in EN 1993-1-12 should be used.

c) Only elastic analysis and design should be used for Class E3 Steel Materials.

Table 3.1 Classification system for various classes of steel materials

Nominal yield strength (N/mm^2)	**Class**	**Compliance with material performance requirements**	**Compliance with quality assurance requirements**	**Additional material tests**	**Material class factor, γ_{MC} for**	
					minimum yield strength, R_{eH}	**ultimate tensile strength, R_m**
≥ 235 and ≤ 690	**E1**	Y	Y	N	1.0	1.0
	E2	Y	N	Y	1.1	1.1
	E3	N	N	N	---	---

3.2.3 Additional material tests required for Class E2 Steel Materials

Table 3.2 summarizes all the additional material tests required for demonstration of conformity of a proposed equivalent steel material in order to achieve classification as a Class E2 Steel Material.

Table 3.2 Additional material tests required for demonstration of conformity

Material tests	Product forms	Parameters tested[a]	Reference Standards
Tensile tests	Plates Sections Hollow sections Sheet piles Solid bars Strips for cold formed open sections Strips for cold formed profiled sheets Stud connectors Bolts	Yield strength Tensile strength Elongation at fracture	BS EN ISO 6892-1
Charpy impact tests	Plates Sections Hollow sections	Impact energy	BS EN ISO 148-1
Hardness Tests	Bolts Nuts Washers	Brinell hardness Vickers hardness Rockwell hardness	BS EN ISO 6506-1 BS EN ISO 6507-1 BS EN ISO 6508-1
Proof load Tests	Nuts	Proof load stress	BS EN ISO 898-2
All-weld metal tests	Welding consumables	Yield strength Tensile strength Elongation at fracture Impact energy	BS EN ISO 15792-1
Chemical Analysis	Plates Sections Hollow sections Sheet piles Solid bars Strips for cold formed open sections Strips for cold-formed profiled sheets Bolts	Carbon content[b], Carbon Equivalent Value[b], Sulphur content[b], Phosphorous content[b], and others[c]	BS EN ISO 14284

It should be noted that

a. All the parameters tested should be in compliance with the material performance requirements given in the relevant acceptable materials specifications.

b. When compared with the limits specified for ladle analysis, limits for product analysis shall be :-

   0.03 % higher for carbon content;
   0.04 % higher for carbon equivalent value;
   0.01 % higher for each of sulphur and phosphorous contents.

c. The contents of the following elements should also be determined and recorded:-

   Silicon (Si), Manganese (Mn), Copper (Cu), Chromium (Cr), Molybdenum (Mo), Nickel (Ni), Aluminium (Al), Niobium (Nb), Titanium (Ti), Vanadium (V), Nitrogen (N) and any other element intentionally added.

As the inspection frequencies, the sampling sizes and the number of tests for each parameter depend on many factors, such as delivery conditions and supply, the structural applications of the steel materials as well as quality assurance requirements and relevant local regulations on the use of equivalent steel materials, it is not practical to provide general recommendations on the programme of material testing. Nevertheless, the practice of quality control on the use of equivalent steel materials adopted by regulatory authorities in a number of countries and cities in Asia is provided in Appendix C for easy reference. It is advisable to seek recommendations from these regulatory authorities for specific additional material tests requirements.

3.2.4 Steel materials with yield strengths larger than 690 N/mm^2

High strength steel materials with yield strengths larger than 690 N/mm^2 are classified as **Class UH Steel Materials** provided that full compliance with all the material performance and the quality assurance requirements to relevant European steel materials specifications is demonstrated during their manufacturing processes. Intensive routine testing should be conducted according to relevant materials specifications whilst the manufacturing process should be demonstrated as operating effectively under a Certified Factory Control Production scheme.

In general, high strength steel materials often offer structural advantages for heavily loaded structures, especially in the case of ultimate limit state design, but there can only be a limited improvement in its resistance to member buckling. Their use makes no improvement to the ability to meet serviceability limit states such as deflection, fatigue etc..

It should be noted that the design provisions in EN 1993 on the use of Class UH Steel Materials are rather limited in extent. Hence, their use in steel construction should be undertaken with caution, and approval from regulatory authorities should be sought. In general, these steel materials are used in bolted members under tension in the form of tie rods or bars, etc.. In these cases, the responsible engineer should provide full justification for the proposed use to the regulatory authority, and also provide a demonstration of compliance with all material performance and quality assurance requirements.

3.3 Material Performance Requirements to European Steel Materials Specifications

The essential material performance requirements for a wide range of product forms are given in this section, and Table 3.3 presents all the product forms covered in this section.

Table 3.3 Product forms

Material type	Material requirements	Product form	Description
Structural steels	Table MR1	Plates	Hot rolled uncoated steel plates with a minimum thickness of 3 mm, supplied flat or pre-curved in any shape as required
	Table MR2	Sections	Hot rolled open sections including universal beams, columns, joists, channels, angles and tees as well as bearing piles
	Table MR3	Hollow sections	Hot finished and cold formed hollow sections of circular, square or rectangular forms
	Table MR4	Sheet piles	Hot rolled and cold formed sheet piles, and interlocking pipe piles
	Table MR5	Solid bars	Hot rolled flat, square and circular steel bars with solid cross-sections
	Table MR6	Strips for cold formed open sections	Hot rolled uncoated or galvanized strips with a thickness in the range of 0.6 to 8 mm for manufacturing of cold formed open sections
Thin gauge strips	Table MR7	Strips for cold formed profiled sheetings	Hot rolled galvanized strips with a thickness in the range of 0.35 to 1.5 mm for manufacturing of cold formed profiled sheetings
Connection materials	Table MR8	Stud connectors	Stud connectors for transferring shear resistances at the steel-concrete interfaces of composite structures
	Table MR9	Non-preloaded bolted assemblies	ISO metric hexagon bolts, nuts and washers for non-preloaded (or bearing) bolted connections
	Table MR10	Preloaded bolted assemblies	ISO metric hexagon bolts, nuts and washers for preloaded (or non-slip) bolted connections
	Table MR11	Welding consumables	Electrodes, wires, rods and fluxes

Compliance with these material performance requirements is one of the two essential selection principles on the equivalence of those steel materials which are not manufactured to European steel materials specifications. However, it should be noted that equivalent steel materials should be manufactured, in the first place, to a national standard, and preferably one of the following national standards:

a) American standards,
b) Japanese standards,
c) Australian/New Zealand standards,
d) Chinese standards, and
e) Russian standards.

At the same time, they should also meet the relevant material performance requirements of the European steel materials specifications as summarized in Tables MR1 to 11 given in this section.

3.3.1 Structural steels

Equivalent steel materials for structural steels as specified in EN 1993-1 should be manufactured to a national standard. Meanwhile, they should also meet the relevant material requirements as specified in Sections 3.3.1.1 to 3.3.1.11.

3.3.1.1 Plates

This section covers hot rolled uncoated steel plates with a minimum thickness of 3 mm which are supplied either flat or pre-curved as required. Steel for cold formed sections and sheetings is not within the scope of this section. References for material performance requirements in this section include, in alphanumerical order, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 1993-1-12, BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5, BS EN 10025-6, BS EN 10029 and BS EN 10051 and BS EN 10164.

Table MR1 Material requirements for plates

a) Geometrical specifications for plates

Dimension	$3 \leq t \leq 150$ mm Deviation in thickness: ±2 mm or within a tolerance of ±15% for thin steel plates.
Mass	7850 kg/m^3, limited by dimensional tolerance.

b) Mechanical specifications for plates

Strength (N/mm^2)	$235 \leq R_{eH} \leq 690$ $300 \leq R_m \leq 1000$
Ductility	$\varepsilon_f \geq 15\%$ and $R_m / R_{eH} \geq 1.10$ for $R_{eH} \leq 460$; $\varepsilon_f \geq 10\%$ and $R_m / R_{eH} \geq 1.05$ for $460 < R_{eH} \leq 690$
Impact toughness	≥ 27 J at specific temperatures.
Through thickness properties	To be specified to BS EN 1993-1-10 and BS EN 10164, if required.

c) Chemical specifications for plates based on ladle analysis

Nominal value of yield strength (N/mm^2)	Maximum content (% by mass)			
	C	P*	S	CEV
235	0.26	0.045	0.050	0.40
275	0.26	0.045	0.050	0.44
355	0.26	0.045	0.050	0.49
420	0.26	0.040	0.050	0.52
460	0.26	0.040	0.050	0.55
500	0.26	0.040	0.030	0.70
550**	0.26	0.030	0.020	0.83
620**	0.26	0.030	0.020	0.83
690**	0.26	0.030	0.020	0.83

* For certain weathering steel, the maximum phosphorous content shall be allowed up to 0.15%.
** For quenched and tempered steel only.

3.3.1.2 Sections

This section covers hot rolled open sections including universal beams, columns, joists, channels, angles and tees as well as bearing piles. References to material performance requirements in this section include, in alphanumerical order, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 10024, BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5, BS EN 10034, BS EN 10055, BS EN 10056-2, BS EN 10164 and BS EN 10279.

Table MR2 Material requirements for sections

a) Geometrical specifications for sections

Dimension	$3 \leq t \leq 63$ mm Deviation in section size: ±4 mm or within a tolerance of ±3%. Deviation in thickness: ±2 mm or within a tolerance of ±15% for thin steel plate.
Mass	7850 kg/m^3, in general, the mass of a batch or piece shall be within ±4% of the calculated mass. For section depth of channels ≤ 125, ±6%. For section depth of channels > 125, ±4%.

b) Mechanical specifications for sections

Strength (N/mm^2)	$235 \leq R_{eH} \leq 500$ $300 \leq R_m \leq 800$
Ductility	$\varepsilon_f \geq 15\%$ and $R_m / R_{eH} \geq 1.10$ for $R_{eH} \leq 460$; $\varepsilon_f \geq 10\%$ and $R_m / R_{eH} \geq 1.05$ for $460 < R_{eH} \leq 500$
Impact toughness	≥ 27 J at specific temperatures.
Through thickness properties	Nil.

c) Chemical specifications for sections based on ladle analysis

Nominal value of yield strength (N/mm^2)	Maximum content (% by mass)			
	C	P*	S	CEV
235	0.26	0.045	0.045	0.40
275	0.26	0.045	0.045	0.44
355	0.26	0.045	0.045	0.49
420	0.26	0.040	0.040	0.52
460	0.26	0.040	0.040	0.55
500	0.26	0.035	0.035	0.49
* For certain weathering steel, the maximum phosphorous content shall be allowed up to 0.15 %.				

3.3.1.3 Hollow sections

This section covers hot finished and cold formed hollow sections of circular, square and rectangular forms. References to material performance requirements in this section include, in alphanumerical order, BS 7668, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 10210-1, BS EN 10210-2, BS EN 10219-1 and BS EN 10219-2.

Table MR3 Material requirements for hollow sections

a) Geometrical specifications for hollow sections

Dimension	$3 \le t \le 80$ mm Deviation in section size: ±2%. Deviation in thickness: ±2mm or within a tolerance of ±15% for thin steel plate.
Mass	7850kg/m^3 , ±6%

b) Mechanical specifications for hollow sections

Strength (N/mm^2)	$235 \le R_{eH} \le 460$ $300 \le R_m \le 750$
Ductility	$\varepsilon_f \ge 15\%$; $R_m / R_{eH} \ge 1.10$
Impact toughness	≥ 27 J at specific temperatures.
Through thickness properties	Nil.

c) Chemical specifications for hot finished hollow sections based on ladle analysis

Nominal value of yield strength (N/mm^2)	Maximum content (% by mass)			
	C	**P***	**S**	**CEV**
235	0.24	0.040	0.040	0.44
275	0.24	0.040	0.040	0.48
355	0.24	0.035	0.035	0.53
420	0.24	0.035	0.035	0.52
460	0.24	0.035	0.035	0.55
* For certain weathering steel, the maximum phosphorous content shall be allowed up to 0.15 %.				

d) Chemical specifications for cold formed hollow sections based on ladle analysis

Nominal value of yield strength (N/mm^2)	Maximum content (% by mass)			
	C	**P***	**S**	**CEV**
235	0.24	0.040	0.040	0.37
275	0.24	0.040	0.040	0.40**
355	0.24	0.035	0.035	0.48**
420	0.24	0.035	0.035	0.43
460	0.24	0.035	0.035	0.53**
* For certain weathering steel, the maximum phosphorous content shall be allowed up to 0.15 %. ** If thermo-mechanical rolling is used, the maximum CEV allowed shall be reduced by 10%.				

3.3.1.4 Sheet piles

This section covers hot rolled and cold formed sheet piles, and interlocking pipe piles. References to material performance requirements in this section include, in alphanumerical order, BS EN 10051, BS EN 10248-1, BS EN 10248-2, BS EN 10249-1 and BS EN 10249-2.

Table MR4 Material requirements for sheet piles

a) Geometrical specifications for sheet piles

Dimension	$t \leq 25$ mm Deviation in cross-sectional dimension: $\pm$ 0.5mm or with a tolerance of $\pm$ 10% for thin steel plates with $t \leq 5$mm.
Mass	7850 kg/m^3, $\pm$ 3%

b) Mechanical specifications for sheet piles

Strength (N/mm^2)	$235 \leq R_{eH} \leq 460$ $300 \leq R_m \leq 750$
Ductility	$\varepsilon_f \geq 15\%$; $R_m / R_{eH} \geq 1.10$
Impact toughness	Nil.
Through thickness properties	Nil.

c) Chemical specifications for sheet piles based on ladle analysis

Nominal value of yield strength (N/mm^2)	**Maximum content (% by mass)**			
	C	**P***	**S**	**CEV**
235 ~ 460	0.25	0.05	0.05	0.48
* For certain weathering steel, the maximum phosphorous content shall be allowed up to 0.15 %.				

3.3.1.5 Solid bars

This section covers hot rolled flat, square and circular steel bars with solid cross-sections. References to material performance requirements in this section include, in alphanumerical order, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 1993-1-12, BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5, BS EN 10025-6, BS EN 10058, BS EN 10059 and BS EN 10060.

Table MR5 Material requirements for solid bars

a) Geometrical specifications for solid bars

Dimension	≤ 150 mm in dimensions for solid bars with square and rectangular cross-sections ≤ 250 mm in diameter for solid bars with circular cross-sections Deviation in cross-sectional dimension: ± 0.5mm or with a tolerance of ± 10% for small cross sections.
Mass	7850 kg/m^3; ±3%

b) Mechanical specifications for solid bars

Strength (N/mm^2)	$235 \le R_{eH} \le 690$ $300 \le R_m \le 1000$
Ductility	$\varepsilon_f \ge 15\%$ and $R_m / R_{eH} \ge 1.10$ for $R_{eH} \le 460$; $\varepsilon_f \ge 10\%$ and $R_m / R_{eH} \ge 1.05$ for $460 < R_{eH} \le 690$
Impact toughness	≥ 27 J at specific temperatures.
Through thickness properties	Nil.

c) Chemical specifications for solid bars based on ladle analysis

Nominal value of yield strength (N/mm^2)	Maximum content (% by mass)		
	P*	S	CEV
235	0.045	0.050	0.40
275	0.045	0.050	0.44
355	0.045	0.050	0.49
420	0.040	0.050	0.52
460	0.040	0.050	0.55
500	0.040	0.030	0.70
550**	0.030	0.020	0.83
620**	0.030	0.020	0.83
690**	0.030	0.020	0.83

* For certain weathering steel, the maximum phosphorous content shall be allowed up to 0.15 %.

** For quenched and tempered steel only.

3.3.1.6 Strips for cold formed open sections

This section covers hot rolled uncoated or galvanized strips with a maximum thickness of 8 mm for manufacturing of cold formed open sections, such as plain or lipped channels and zeds for building envelopes. References for material performance requirements in this section include, in alphanumerical order, BS EN 1993-1-3, BS EN 1993-1-12, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10268, BS EN 10346, BS EN 10149-2, BS EN 10149-3, BS EN 10051, and BS EN 10143.

Table MR6 Material requirements for cold formed open sections

a) Geometrical specifications for strips for cold formed open sections

Dimension	$0.6 \leq t \leq 8$ mm Deviation in actual thickness:	 $\pm$0.3 mm or with a tolerance of $\pm$15% for thin strips.
Mass	7850kg/m^3, limited by dimensional tolerance.	

b) Mechanical specifications for strips for cold formed open sections

Strength (N/mm^2)	$200 \leq R_{eH} \leq 700$ $250 \leq R_m \leq 1000$		
Ductility	$\varepsilon_f \geq 15\%$ and $R_m / R_{eH} \geq 1.10$ $\varepsilon_f \geq 10\%$ and $R_m / R_{eH} \geq 1.05$	for for	$R_{eH} \leq 460$; $460 < R_{eH} \leq 700$
Impact toughness	Nil.		
Through thickness properties	Nil.		

c) Chemical specifications for strips for cold formed open sections based on ladle analysis

Nominal value of yield strength (N/mm^2)	**Maximum content (% by mass)**			
	C	**P**	**S**	**CEV**
200 ~ 355	0.25	0.10	0.05	0.45
420 ~ 550	0.25	0.10	0.05	-
600 ~ 700	0.15	0.03	0.02	-
Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and should be referred to BS EN 10025-2, BS EN 10025-3 , BS EN 10025-4, BS EN 10149-2, BS EN 10149-3, BS EN 10268 and BS EN 10346.				

3.3.1.7 Strips for cold formed profiled sheetings

This section covers hot rolled galvanized strips with thicknesses ranging from 0.43 to 1.5 mm for the manufacture of cold formed profiled sheetings in metal roof and composite slab construction. References to material performance requirements in this section include, in alphanumerical order, BS EN 1993-1-3, BS EN 1993-1-12, BS EN 10025-2 , BS EN 10025-3 , BS EN 10025-4, BS EN 10268, BS EN 10346, BS EN 10149-2, BS EN 10149-3, BS EN 10051 and BS EN 10143.

Table MR7 Material requirements for cold formed profiled sheetings

a) Geometrical specifications for strips for cold formed profiled sheetings

Dimensions	$0.35 \leq t \leq 1.5$ mm Deviation in actual thickness: $\pm$0.1mm or with a tolerance of $\pm$15% for thin strips.
Mass	7850kg/m^3, limited by dimensional tolerance.

b) Mechanical specifications for strips for cold formed profiled sheetings

Strength (N/mm^2)	$200 \leq R_{eH} \leq 700$ $250 \leq R_m \leq 1000$
Ductility	$\varepsilon_f \geq 15\%$; R_m / $R_{eH} \geq 1.10$ and $\varepsilon_u \geq 15\ \varepsilon_y$ for $R_{eH} < 460$; $\varepsilon_f \geq 10\%$; R_m / $R_{eH} \geq 1.05$ and $\varepsilon_u \geq 15\ \varepsilon_y$ for $460 \leq R_{eH} \leq 700$
Impact toughness	Nil.
Through thickness properties	Nil.

* Note: When the yield point is not pronounced, the value of R_e should be taken as the 0.2% proof strength, $R_{p0.2}$. If the yield strength is pronounced, the value of R_e should be taken as the lower yield strength R_{eL} according to the product standard.

c) Chemical specifications for strips for cold formed profiled sheetings based on ladle analysis

Nominal value of yield strength (N/mm^2)	Maximum content (% by mass)			
	C	P	S	CEV
200 ~ 355	0.25	0.10	0.05	0.45
420 ~ 550	0.25	0.10	0.05	-
600 ~ 700	0.15	0.03	0.02	-
Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and should be referred to BS EN 10025-2, BS EN 10025-3 , BS EN 10025-4, BS EN 10149-2, BS EN 10149-3, BS EN 10268 and BS EN 10346.				

3.3.1.8 Stud connectors

This section covers stud connectors which are used to transfer shear resistances across the steel-concrete interfaces of composite members. References to material performance requirements in this section include, in alphanumerical order, BS EN 1994-1-1, BS EN ISO 13918, and BS EN ISO 898-1.

Table MR8 Material requirements for stud connectors

a) Geometrical specifications for stud connectors

Shank diameter	10 to 25 mm
Dimensional tolerance	In accordance with the corresponding standards.

The head diameter should be at least 1.5 times the shank diameter whereas the head depth should be a least 0.4 times the shank diameter.

b) Mechanical specifications for stud connectors

Nominal value of yield strength (N/mm^2)	$240 \leq R_e * \leq 1100$ $R_m \geq 400$
Ductility	$\varepsilon_f \geq 14\%$

* Note: When the yield point is not pronounced, the value of R_e should be taken as the 0.2% proof strength, $R_{p0.2}$. If the yield strength is pronounced, the value of R_e should be taken as the lower yield strength R_{eL} according to the product standard.

3.3.1.9 Non-preloaded bolted assemblies

This section covers non-preloaded bolts and the recommended combinations of matching components in non-preloaded bolted assemblies. It covers ISO metric hexagon bolts, nuts and washers for non-preloaded (or bearing) bolted connections with bolts, plain washers with or without chamfers. References to material performance requirements in this section include, in alphanumerical order, BS 4190, BS 7419, BS EN 1993-1-8, BS EN ISO 898-1, BS EN ISO 898-2, , BS EN ISO 898-3, BS EN ISO 4014, BS EN ISO 4016, BS EN ISO 4017, BS EN ISO 4018, BS EN ISO 4032, BS EN ISO 4033, BS EN ISO 4034, BS EN ISO 7091, BS EN ISO 7092, BS EN ISO 7093-1, BS EN ISO 7093-2, and BS EN ISO 7094.

Table MR9 Material requirements for non-preloaded bolted assemblies

a) Geometrical specifications for non-preloaded bolted assemblies

Thread size	5 ~ 68 mm
Dimensions	In accordance with the corresponding standards.

b) Mechanical specifications for non-preloaded bolts

Strength (N/mm^2)	Grade of bolts	R_m	R_e*
	4.6	400	240
	8.8	800	640
	10.9	1000	900
	12.9	1200	1080
Ductility	$\varepsilon_f \geq 8\%$ Reduction in area after fracture, $A \geq 44\%$		

* Note: When the yield point is not pronounced, the value of R_e should be taken as the 0.2% proof strength, $R_{p0.2}$. If the yield strength is pronounced, the value of R_e should be taken as the lower yield strength R_{eL} according to the product standard.

c) Hardness requirements for non-preloaded bolts

Grade of bolts	Range of hardness		
	Vickers hardness (HV)	**Brinell hardness (HB)**	**Rockwell hardness (HRB or HRC)**
4.6	120 – 220	114 – 209	67 – 95 (HRB)
8.8	250 – 335	238 – 318	22 – 34 (HRC)
10.9	320 – 380	304 – 361	32 – 39 (HRC)
12.9	385 – 435	380 – 429	39 – 44 (HRC)

d) Chemical specifications for non-preloaded bolts based on product analysis

Grade of bolts	Maximum content (% by mass)	
	P	**S**
4.6*	0.050	0.060
8.8 and 10.9**	0.050	0.060
12.9	0.025	0.025

* Free cutting steel may be allowed for these grades with the following maximum contents: Sulphur 0.34 %, Phosphorous 0.11 % and Lead 0.35 %.

** In case of plain carbon boron steel with a carbon content below 0.25% (cast analysis), the minimum manganese content should be 0.6% for property class 8.8, and 0.7% for property class 10.9.

e) Recommended grades of nuts in non-preloaded assemblies

Grade of nuts	**Proof load stress (N/mm^2)**	**Compatible bolt grades**
4	400	≤ 4.8
8	800	≤ 8.8
10	1000	≤ 10.9
12	1200	≤ 12.9

f) Hardness requirements for nuts in non-preloaded assemblies

Grade of nuts	**Range of hardness**		
	Vickers Hardness (HV)	**Brinell hardness (HB)**	**Rockwell hardness (HRC)**
≤ 8	≤ 310	≤ 302	≤ 30
10	≤ 370	≤ 353	≤ 36
12	≤ 395	≤ 375	≤ 39

g) Chemical specifications for nuts in non-preloaded assemblies based on product analysis

Grade of nuts	Maximum content (% by mass)		
	C	P	S
≤ 6	0.50	0.110	0.150
8	0.58	0.060	0.150
10 and 12	0.58	0.048	0.058
Free cutting steel may be allowed for these grades with the following maximum contents: Sulphur 0.34 %, Phosphorus 0.11%, and Lead 0.35 %.			

3.3.1.10 Preloaded bolted assemblies

This section covers preloaded bolts and the recommended combinations of matching components in preloaded bolted assemblies. It covers ISO metric hexagon bolts, nuts and washers for preloaded (or non-slip) bolted connections. References to material performance requirements in this section include, in alphanumerical order, BS EN 1993-1-8, BS EN 14399-1, BS EN 14399-2, BS EN 14399-3, BS EN 14399-4, BS EN 14399-5, BS EN 14399-6, BS EN 14399-7, BS EN 14399-8, BS EN 14399-9, BS EN ISO 898-1 and BS EN ISO 898-2.

Table MR10 Material requirements for preloaded bolted assemblies

a) Geometrical specifications for preloaded bolted assemblies

Thread size	12 to 36mm
Dimensions	In accordance with the corresponding standards.

Bolts with thread sizes should be in the range of 12 to 36 mm with plain washers with or without chamfers, and tension indicating washers.

b) Mechanical specifications for preloaded bolts

Strength (N/mm^2)	Grade of Wbolts	R_m	R_e*
	8.8	800	640
	10.9	1000	900
	12.9	1200	1080
Ductility	$\varepsilon_f \geq 8\%$		
Impact toughness	≥ 27 J at -20 °C.		

* Note: When the yield point is not pronounced, the value of R_e should be taken as the 0.2% proof strength, $R_{p0.2}$. If the yield strength is pronounced, the value of R_e should be taken as the lower yield strength R_{eL} according to the product standard.

c) Hardness requirements for preloaded bolts

Grade of bolts	Range of hardness		
	Vickers hardness (HV)	**Brinell hardness (HB)**	**Rockwell hardness (HRC)**
8.8	250 – 335	238 – 318	22 – 34
10.9	320 – 380	304 – 361	32 – 39
12.9	385 – 435	380 – 429	39 – 44

d) Chemical specifications for preloaded bolts based on product analysis

Grade of bolts	Maximum content (% by mass)	
	P	**S**
4.6*	0.050	0.060
8.8 and 10.9**	0.050	0.060
12.9	0.025	0.025

* Free cutting steel may be allowed for these grades with the following maximum contents: Sulphur 0.34 %, Phosphorous 0.11 % and Lead 0.35 %.

** In case of plain carbon boron steel with a carbon content below 0.25% (cast analysis), the minimum manganese content should be 0.6% for property class 8.8, and 0.7% for property class 10.9.

e) Recommended grades of nuts in preloaded assemblies

Grade of nuts	Proof load stress (N/mm^2)	Compatible bolt grades
8	800	≤ 8.8
10	1000	≤ 10.9
12	1200	≤ 12.9

f) Hardness requirements for nuts in preloaded assemblies

Grade of nuts	Range of hardness		
	Vickers Hardness (HV)	Brinell hardness (HB)	Rockwell hardness (HRC)
≤ 8	≤ 310	≤ 302	≤ 30
10	≤ 370	≤ 353	≤ 36
12	≤ 395	≤ 375	≤ 39

g) Chemical specifications for nuts in preloaded assemblies based on product analysis

Grade of nuts	Maximum content (% by mass)		
	C	P	S
8	0.58	0.06	0.15
10 and 12	0.58	0.05	0.06

3.3.1.11 Welding consumables

This section covers welding consumables including electrodes, wires, rods and fluxes. The design parameters of welds corresponding to different welding consumable grades are given in Table MR11. References to material performance requirements in this section include, in alphanumerical order, BS EN ISO 14174, BS EN 1993-1-8, BS EN ISO 636, BS EN ISO 2560, BS EN ISO 15792-1, BS EN ISO 15792-2, BS EN ISO 15792-3, BS EN ISO 14171, BS EN ISO 16834, BS EN ISO 17632, BS EN ISO 17633, BS EN ISO 17634, BS EN ISO 18274, BS EN ISO 21952, BS EN ISO 24373, BS EN ISO 24598, BS EN ISO 26304, , BS EN ISO14343 and BS EN ISO 14341.

Table MR11 Material requirements for welding consumables

a) Material performance requirements for welding consumables

Material performance requirements	In accordance with the corresponding standards.

b) Mechanical specifications for welding consumables

Strength (N/mm^2)	$250 \leq R_e^* \leq 890$ $430 \leq R_m \leq 1200$
Ductility	$\varepsilon_f \geq 15\%$
Impact toughness	≥ 27 J at specific temperatures.

* Note: When the yield point is not pronounced, the value of R_e should be taken as the 0.2% proof strength, $R_{p0.2}$. If the yield strength is pronounced, the value of R_e should be taken as the lower yield strength R_{eL} according to the product standard.

3.4 Quality Assurance Requirements to European Steel Materials Specifications

In general, a steel manufacturer will have already established a form of quality assurance. However, in order to demonstrate compliance with the quality assurance requirements for steel materials equivalent to European steel materials specifications, a steel manufacturer should further establish a Factory Production Control (FPC) System which is essential for demonstrating conformity of the steel material performances with European steel materials specifications. Moreover, in order to demonstrate effective implementation, the FPC System must be certified by an independent qualified certification body. For further information on a FPC Scheme, refer to Appendix B.4 of EN 10025-1.

3.4.1 Factory Production Control System

A steel manufacturer should establish, document and maintain a FPC System to ensure conformity of his steel products with relevant materials specifications. In addition to a quality management system as well as an inspection system, he should carry out regular monitoring at least once a year as well as continuous surveillance. More importantly, he should perform material tests regularly in order to demonstrate full conformity of the proposed steel material with the relevant European materials specifications. All the material tests should be performed in accordance with the material testing standards listed in Section 3.2.3 or other relevant standards.

3.4.1.1 Requirements for Factory Production Control System

The steel manufacturer is fully responsible for administrating the effective implementation of a FPC System during the manufacturing process of the steel material. He should draw up detailed technical specifications as well as effective quality assurance schemes which are appropriate to the steel material and the manufacturing process. He should also clearly define specific tasks and associated responsibilities of the tasks among various parties, and keep up-to-date documents defining the FPC System. Key tasks in the FPC System include:

- to identify procedures to demonstrate conformity of the material performances of the steel material at appropriate stages;
- to identify and record any incident of non-conformity; and
- to identify procedures to correct incidents of non conformity.

The FPC System should achieve an appropriate level of confidence in the conformity of the material performance of the steel material, and this involves:

- documentation of procedures according to various requirements given in relevant technical specifications;
- effective implementation of these procedures;
- recording details of these procedures in operation and their results;
- use of these results to correct any deviation, repair effects of such deviation, correct any incident of non-conformity, and if necessary, revise the FPC System to rectify the cause of non-conformity.

It should also be noted that FPC procedures include some or all of the following:

- to specify and verify raw materials and constituents of the steel material;
- to conduct material tests on the steel material during manufacturing according to a pre-determined frequency;
- to conduct verification tests on finished products of the steel material according to a frequency which may be pre-determined in technical specifications, and adapted to the product and its conditions of manufacturing.

3.4.1.2 Raw materials

The steel manufacturer should ensure that both the specifications of all incoming raw materials and the inspection scheme related to these raw materials are properly documented to ensure their conformity.

3.4.1.3 Equipment

The steel manufacturer should calibrate regularly and inspect all weighing, measuring and testing equipment according to established practice as to procedures, criteria and frequencies. He should also inspect and maintain all manufacturing equipment regularly to ensure that use, wear or failure does not result in product inconsistency in the manufacturing process. Inspection and maintenance should be performed in accordance with the manufacturer's written procedures, and records of inspection and maintenance should be retained for the period defined in the manufacturer's FPC procedures.

3.4.1.4 Verifications and tests

The steel manufacturer should have suitable installations, equipment and personnel which enable him to conduct all necessary verifications and tests. He must calibrate, verify and maintain all measuring and testing equipment in good operating condition to enable him to demonstrate conformity of the steel material performance with its technical specification.

3.4.1.5 Monitoring of conformity

The steel manufacturer should monitor conformity of the steel material at various intermediate as well as the main stages of the manufacturing process. This monitoring of conformity focuses on the product throughout the manufacturing process so that only products which have passed the scheduled intermediate controls and tests are dispatched.

3.4.1.6 Testing with direct and indirect methods

The steel manufacturer should conduct tests in accordance with the test plan, and all of these tests should be carried out in accordance with the methods described in relevant technical specifications. In general, these methods should be direct methods.
However, it is possible in the case of certain characteristics that the prescribed specification allows for a possibility of using indirect test methods if a definite relationship can be established. In such case, indirect test methods may be retained when available and appropriate.

3.4.1.7 Test records

The steel manufacturer should keep test records which provide evidence that the steel material product has been thoroughly tested. These test records should show clearly whether the product has satisfied all the steel material performance requirements. Where the product fails to satisfy any particular requirement, provisions for non-conforming products should apply as in Section 3.4.1.8.

3.4.1.8 Treatment of products which do not conform

If test results show that the product of the steel material does not meet a particular requirement, for example, if the statistical variation of test results exceeds the limits allowed by the technical specification, appropriate corrective action should be taken immediately. Moreover, products or batches of products not conforming should be isolated and properly identified. Once the fault has been corrected, verification against that requirement should be repeated. If products have been delivered before the results are available, a procedure for notifying customers should be established and recorded.

3.4.1.9 Record of verifications and tests

The steel manufacturer should properly record the control results of the FPC System:

i) product description,
ii) date of manufacture,
iii) test method adopted,
iv) test results and acceptance criteria.

All of these results should be properly recorded. With regard to any result not meeting a requirement of the technical specification, any corrective measure taken to rectify the situation should be clearly documented.

3.4.1.10 Traceability

The steel manufacturer should keep full records of individual products or product batches of the steel material, including manufacturing details and characteristics, and keep records of clients. Individual products or batches of products and the related manufacturing details should be completely identifiable and retraceable. However, it should be noted that in certain cases, for example for bulk products, a rigorous traceability is not possible.

Hence, the requirement in the relevant technical specifications should be realistically adapted keeping in view that traceability should be as complete as possible.

Section 4 Design Parameters for Equivalent Steel Materials

This Chapter presents design data for those steel materials which have demonstrated they meet the material performance and the quality assurance requirements representing the equivalence of steel materials as detailed in Chapter 3. Design parameters of the equivalent steel materials for various product forms are also tabulated in Tables 4.2 to 4.9 to allow direct adoption when designing structural steelwork in accordance with EN 1993 and EN 1994. It should be noted that a detailed technical examination of a large number of material specifications of the five countries of interest had been conducted. Acceptable steel materials specifications and steel grades are given in the "Code of Practice for the Structural Use of Steel" (2005 & 2011) of the Buildings Department of the Government of Hong Kong SAR, and in the "Design Guide on Use of Alternative Structural Steel to BS5950 and Eurocode 3" (2008 & 2012) of the Building and Construction Authority of the Ministry of National Development in Singapore. A full list of acceptable steel materials manufactured to the national materials specifications of the four countries of interest is provided in Appendix A for easy reference.

4.1 Product Forms of Equivalent Steel Materials

Table 4.1 presents all the product forms of various classes of equivalent steel materials for easy reference.

Table 4.1 Product forms of various classes of equivalent steel materials

Class	Steel Materials	Product forms	Cross-referencing
E1	Structural steels	Plates, sections, hollow sections, sheet piles, solid bars, strips for cold formed sections	4.2.1 Table 4.2
	Thin gauge strips	strips for cold formed sheeting	4.2.2, Table 4.3
	Connection materials	stud connectors, non-preloaded bolted assemblies, preloaded bolted assemblies, welding consumables	4.2.3 Tables 4.4 to 4.7
E2	Structural steels	plates, sections, hollow sections, sheet piles, solid bars, strips for cold formed sections	4.3.1 Table 4.8
	Thin gauge strips	strips for cold formed sheeting	4.3.2
	Connection materials	stud connectors non-preloaded bolted assemblies preloaded bolted assemblies welding consumables	4.3.3
E3	Structural steels	Plates, sections, hollow sections, sheet piles, solid bars, strips for cold formed sections	4.4.1 Table 4.9

Refer to Section 3.2.2 for the definitions of the classification of steel materials, and Equations 3.1 and 3.2 for the nominal values of yield and ultimate tensile strengths of the equivalent steel materials to be used in structural calculations.

4.2 Design Parameters for Class E1 Equivalent Steel Materials

This section presents the design guidance on Class E1 Steel materials for which compliance with all the material requirements has been demonstrated through **intensive routine testing** conducted during the effective implementation of a certificated **Factory Production Control** system according to European steel materials specifications. The corresponding material class factor γ_{MC} should be taken as 1.0.

4.2.1 Class E1 Structural steels

This section covers the design parameters of Class E1 Structural steels including

i) hot rolled plates, sections, hollow sections, sheet piles, solid bars,
ii) hot rolled strips for cold formed sections.

The design parameters of Class E1 Structural steels corresponding to different steel grades of various national steel materials specifications are given in Table 4.2.

Table 4.2a Design parameters of Structural steels to European (EN) specifications

Grade	Minimum yield strength R_{ehm} (N/mm^2) for thickness (mm) less than or equal to					
	16	**40**	**63**	**80**	**100**	**150**
S235	235*	225	215	215	215	195
S275	275	265	255	245	235*	225*
S355	355	345	335	325	315*	295*
S420	420	400	390	370*, **	360*, **	340*, **
S460	460	440	430***	410***	400***	380*, **, ***
S500	500	480***	460***	450***	450***	450***
S550	550	550	550***	530	530	490
S620	620	620	620***	580	580	560
S690	690	690	690***	650	650	630
Grade	**Tensile strength R_m (N/mm^2) for thickness (mm) less than or equal to**					
	16	**40**	**63**	**80**	**100**	**150**
S235	360 ~ 510					350 ~ 500
S275	350 ~ 560					350 ~ 480
S355	440 ~ 630					430 ~ 600
S420	470 ~ 680					460 ~ 650
S460	500 ~ 720					480 ~ 710
S500	590 ~ 770					560 ~ 750
S550	640 ~ 820					590 ~ 770
S620	700 ~ 890					650 ~ 830
S690	760 ~ 940					710 ~ 900

* For Thermo-mechanical Rolled Weldable Steels, R_{eHm} is high and should be refer to EN 10025-4.
** For Atmospheric Resistance Steels, R_{eHm} is higher and should be refer to EN 10025-5.
*** For High Strength Structural Steels in the Quenched and Tempered Condition, R_{eHm} is higher and should be refer to EN 10025-6, and the thickness limit is 50 mm instead of 63 mm.

Table 4.2b Design parameters of Class E1 Structural steels to American (ASTM and API) specifications

Grade	**Minimum yield strength R_{eH} (N/mm^2) for thickness (mm) less than or equal to**				
	32	**50**	**65**	**80**	**100**
ASTM structural steels					
36 [250]	250				
42[290]	290				
50 [345]	345				
55 [380]	380				
60 [415]	415				
65 [450]	450				
70 [485]	485				
100 [690]	690			620	
API line pipes					
B [L245]	245				-
X42 [L290]	290				-
X46 [L320]	320				-
X52 [L360]	360				-
X56 [L390]	390				-
X60 [L415]	415				-
X65 [L450]	450				-
X70 [L485]	485				
Grade	**Tensile strength R_m (N/mm^2) for thickness (mm) less than or equal to**				
	32	**50**	**65**	**80**	**100**
ASTM structural steels					
36 [250]	365 ~ 550				
42[290]	415				
50 [345]	435 ~ 620				
55 [380]	480 ~ 485				
60 [415]	450 ~ 520				
65 [450]	450 ~ 690				
70 [485]	570 ~ 760				
100 [690]	760 ~ 895			690 ~ 895	
API line pipes					
B [L245]	415				-
X42 [L290]	415				-
X46 [L320]	435				-
X52 [L360]	460				-
X56 [L390]	490				-
X60 [L415]	520				-
X65 [L450]	535				-
X70 [L485]	570				

Table 4.2c Design parameters of Class E1 Structural steels to Japanese (JIS) specifications

Grade	Minimum yield strength R_{eH} (N/mm^2) for thickness (mm) less than or equal to					
	16	40	75	100	160	200
JIS structural steels						
400	245	235	215	215	205	195
490	325	315	295	295	285	275
490Y	365	355	335	325	-	-
520	365	355	335	325	-	-
570	460	450	430	420	-	-
JIS s heet piles						
295	295	-				
390	390	-				
430	430	-				
Grade	**Tensile strength R_m (N/mm^2) for thickness (mm) less than or equal to**					
	16	**40**	**75**	**100**	**160**	**200**
JIS structural steels						
400	400 ~ 510					
490	490 ~ 610					
490Y	490 ~ 610				-	-
520	520 ~ 640				-	-
570	570 ~ 720				-	-
JIS s heet piles						
295	450	-				
390	490	-				
430	510	-				

Table 4.2d Design parameters of Class E1 Structural steels to Australian/New Zealand (AS/NZS) specifications

<table>
<tr><th rowspan="2">Grade</th><th colspan="8">Minimum yield strength R_{eH} (N/mm2)
for
thickness (mm) less than or equal to</th></tr>
<tr><th>8</th><th>12</th><th>20</th><th>32</th><th>50</th><th>80</th><th>150</th><th>200</th></tr>
<tr><td>200</td><td>200</td><td>200</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td></td></tr>
<tr><td>250</td><td>280</td><td>260</td><td>250</td><td>250</td><td>250</td><td>240</td><td>230</td><td>220</td></tr>
<tr><td>300</td><td>320</td><td>310</td><td>300</td><td>280</td><td>280</td><td>270</td><td>260</td><td>250</td></tr>
<tr><td>350</td><td>360</td><td>360</td><td>350</td><td>340</td><td>340</td><td>340</td><td>330</td><td>320</td></tr>
<tr><td>400</td><td>400</td><td>400</td><td>380</td><td>360</td><td>360</td><td>360</td><td>-</td><td>-</td></tr>
<tr><td>450</td><td>450</td><td>450</td><td>450</td><td>420</td><td>400</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA220</td><td>210</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA260</td><td>250</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA350</td><td>350</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA500</td><td>500</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>PT430</td><td colspan="2">300*</td><td>280</td><td>280</td><td>280*</td><td>270</td><td>250</td><td>-</td></tr>
<tr><td>PT460</td><td colspan="2">305*</td><td>295</td><td>295</td><td>295*</td><td>275</td><td>265</td><td>-</td></tr>
<tr><td>PT490</td><td colspan="2">360*</td><td>340</td><td>340</td><td>340*</td><td>330</td><td>320</td><td>-</td></tr>
<tr><td>PT540</td><td colspan="2">450*</td><td>420</td><td>420</td><td>420*</td><td></td><td>-</td><td>-</td></tr>
<tr><th rowspan="2">Grade</th><th colspan="7">Tensile strength R_m (N/mm^2)
for
thickness (mm) less than or equal to</th><th></th></tr>
<tr><th>8</th><th>12</th><th>20</th><th>32</th><th>50</th><th>80</th><th>150</th><th>200</th></tr>
<tr><td>200</td><td colspan="7">300</td><td>290</td></tr>
<tr><td>250</td><td colspan="7">410</td><td>400</td></tr>
<tr><td>300</td><td colspan="7">430</td><td>420</td></tr>
<tr><td>350</td><td colspan="8">450</td></tr>
<tr><td>400</td><td colspan="6">480</td><td>-</td><td>-</td></tr>
<tr><td>450</td><td colspan="3">520</td><td colspan="2">500</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA220</td><td>340</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA260</td><td>350</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA350</td><td>430</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CA500</td><td>510</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>PT430</td><td colspan="7">430 ~ 550</td><td>-</td></tr>
<tr><td>PT460</td><td colspan="7">460 ~ 580</td><td>-</td></tr>
<tr><td>PT490</td><td colspan="7">490 ~ 610</td><td>-</td></tr>
<tr><td>PT540</td><td colspan="5">540 ~ 670*</td><td>-</td><td>-</td><td>-</td></tr>
</table>

* For Fine grained, weldable steel plates, the thickness limits are 16 mm and 40 mm instead of 12 mm and 50 mm separately.

Table 4.2e Design parameters of Class E1 Structural steels to Chinese (GB) specifications

<table>
<tr><th rowspan="2">Grade</th><th colspan="6">Minimum yield strength R_{eH} (N/mm^2)
for
thickness (mm) less than or equal to</th></tr>
<tr><th>16</th><th>35</th><th>50</th><th>100</th><th>150</th><th>200</th></tr>
<tr><td>Q235</td><td>235</td><td>225</td><td>215</td><td>215</td><td>195</td><td>185</td></tr>
<tr><td>Q275</td><td>275</td><td>265</td><td>255</td><td>245</td><td>225</td><td>215</td></tr>
<tr><td>Q295</td><td>295</td><td>285</td><td>275</td><td>255</td><td>-</td><td>-</td></tr>
<tr><td>Q345</td><td>345</td><td>345</td><td>345</td><td>335</td><td>325</td><td>305</td></tr>
<tr><td>Q355</td><td>355</td><td>345</td><td>335</td><td>315</td><td>295</td><td>285</td></tr>
<tr><td>Q390</td><td>390</td><td>380</td><td>360</td><td>340</td><td>320</td><td>310</td></tr>
<tr><td>Q420</td><td>420</td><td>400</td><td>390</td><td>360</td><td>340</td><td>330</td></tr>
<tr><td>Q460</td><td>460</td><td>440</td><td>430</td><td>400</td><td>380</td><td>370</td></tr>
<tr><td>Q500</td><td>500</td><td>490</td><td>480</td><td>450</td><td>440</td><td>-</td></tr>
<tr><td>Q550</td><td>550</td><td>540</td><td>530</td><td>500</td><td>490</td><td>-</td></tr>
<tr><td>Q620</td><td>620</td><td>610</td><td>590</td><td>580</td><td>560</td><td>-</td></tr>
<tr><td>Q690</td><td>690</td><td>680</td><td>670</td><td>650</td><td>630</td><td>-</td></tr>
<tr><th rowspan="2">Grade</th><th colspan="6">Tensile strength R_m (N/mm^2)
for
thickness (mm) less than or equal to</th></tr>
<tr><th>16</th><th>35</th><th>50</th><th>100</th><th>150</th><th>200</th></tr>
<tr><td>Q235</td><td colspan="5">370 ~ 500</td><td>-</td></tr>
<tr><td>Q275</td><td colspan="5">410 ~ 540</td><td>-</td></tr>
<tr><td>Q295</td><td colspan="4">430 ~ 560</td><td>-</td><td>-</td></tr>
<tr><td>Q345</td><td colspan="4">490 ~ 610</td><td colspan="2">470 ~ 610</td></tr>
<tr><td>Q355</td><td colspan="2">470 ~ 630</td><td>450 ~ 610</td><td>440 ~ 600</td><td colspan="2">450 ~ 600</td></tr>
<tr><td>Q390</td><td colspan="2">490 ~ 650</td><td>480 ~ 640</td><td>480 ~ 640</td><td colspan="2">470 ~ 620</td></tr>
<tr><td>Q420</td><td colspan="2">520 ~ 680</td><td>500 ~ 660</td><td>470 ~ 630</td><td colspan="2">500 ~ 650</td></tr>
<tr><td>Q460</td><td colspan="2">540 ~ 720</td><td>530 ~ 710</td><td>500 ~ 680</td><td colspan="2">530 ~ 710</td></tr>
<tr><td>Q500</td><td colspan="2">610 ~ 770</td><td>600 ~ 760</td><td>540 ~ 730</td><td>540 ~ 720</td><td>-</td></tr>
<tr><td>Q550</td><td colspan="2">670 ~ 830</td><td>620 ~ 810</td><td>590 ~ 780</td><td>590 ~ 770</td><td>-</td></tr>
<tr><td>Q620</td><td colspan="2">710 ~ 880</td><td>690 ~ 880</td><td>670 ~ 860</td><td>650 ~ 830</td><td>-</td></tr>
<tr><td>Q690</td><td colspan="2">770 ~ 940</td><td>750 ~ 920</td><td>730 ~ 900</td><td>710 ~ 900</td><td>-</td></tr>
</table>

Table 4.2f Design parameters of Class E1 Structural steels to Russian(GOST) specifications

Grade	Minimum yield strength R_{eH} (N/mm²) for thickness (mm) less than or equal to					
	16	40	60	80	100	160
C245 (Ст3Ххх**)	235	225	215	215	215	195
C255 (Ст4кп)	245	235	235	235	235	-
C345	325	305	285	275	265	265
C355	355	345	335	325	315	295
C390	390	380	380*	-	-	-
C440	440	440	440*	-	-	-
C550	540	540	540*	-	-	-
C590	590	590	590*	-	-	-
265 (Ст4хх**)	265	255	245	245	245	235
295 (Ст5хх**)	285	275	265	265	265	255
315	315	315	315	-	-	-
325	325	325	325	-	-	-
345	345	345	345	-	-	-
355	355	355	355	-	-	-
375	375	375	375	-	-	-
390	390	390	390	-	-	-
440	440	440	440	-	-	-
460	460	460	460	-	-	-
Grade	**Tensile strength R_m (N/mm²) for thickness (mm) less than or equal to**					
	16	**40**	**60**	**80**	**100**	**160**
C245 (Ст3Ххх**)	360 ~ 460					
C255 (Ст4кп)	370		400 ~ 510			-
C345	470	460	450	440	430	430
C355	470	470	470	460	460	460
C390	520	520	520*	-	-	-
C440	540	540	540*	-	-	-
C550	640	640	640*	-	-	-
C590	685	685	685*	-	-	-
265 (Ст4хх**)	410~530					
295 (Ст5хх**)	450~590					
315	450	450	450	-	-	-
325	450	450	450	-	-	-
345	490	490	490	-	-	-
355	490	490	490	-	-	-
375	510	510	510	-	-	-
390	510	510	510	-	-	-
440	590	590	590	-	-	-
460	540~720	540~720	540~720	-	-	-

* Thickness is no more than 50mm.

**. Steel grades are Ст3кп, Ст3пс, Ст3сп, Ст3Гпс, Ст3Гсп, Ст4пс, Ст4сп, Ст5Гпс.

4.2.2 Class E1 Thin gauge strips

The design parameters of Class E1 Thin gauge strips (hot rolled strips) for cold formed profiled sheetings corresponding to different steel grades of various national steel materials specifications are given in Table 4.3.

Table 4.3a Design parameters of Thin gauge strips to European (EN) specifications

Grade	Minimum yield strength R_e (N/mm²)	Tensile strength R_m (N/mm²)
S220GD	220	300
S250GD	250	330
S280GD	280	360
S320GD	320	390
S350GD	350	420
S550GD	550	560

Table 4.3b Design parameters of Class E1 Thin gauge strips to American (ASTM) specifications

Grade	Minimum yield strength R_e (N/mm²)	Tensile strength R_m (N/mm²)
230	230	310
255	255	360
275	275	360
340	340	410
380	380	480
410	410	480
480	480	550
550	550	570

Table 4.3c Design parameters of Class E1 Thin gauge strips to Japanese (JIS) specifications

Grade	Minimum yield strength R_e (N/mm²)	Tensile strength R_m (N/mm²)
340	245	340
400	295	400
440	335	440
490	365	490
540	400	540

Table 4.3d Design strengths of Class E1 Thin gauge strips to Australian/New Zealand (AS/NZS) specifications

Grade	Minimum yield strength R_e (N/mm²)	Tensile strength R_m (N/mm²)
250	250	320
300	300	340
350	350	420
450	450	480
500	500	520
550	550	550

Table 4.3e Design parameters of Class E1 Thin gauge strips to Chinese (GB) specifications

Grade	Minimum yield strength R_e (N/mm²)	Tensile strength R_m (N/mm²)
220	220	300
250	250	330
280	280	360
300	300	370
320	320	390
350	350	420
420	420	480
450	450	510
550	550	560

Table 4.3f Design parameters of Class E1 Thin gauge strips to Russian(GOST) specifications

Grade	Minimum yield strength R_e (N/mm²)	Tensile strength R_m (N/mm²)
02	^	270 - 500
03	^	270 - 420
04	260	270 - 380
05	220	270 - 350
220	220	300
250	250	330
280	280	360
320	320	390
350	350	420
295	295	410
315	315	430
345	345	460
355	355	480
390	390	500

4.2.3 Class E1 Connection materials

This section covers the design parameters of Class E1 Connection materials including

i) Stud connectors
ii) Non-preloaded bolted assemblies
iii) Preloaded bolted assemblies
iv) Welding consumables.

4.2.3.1 Class E1 Stud connectors

The design parameters for Class E1 Stud connectors corresponding to various national steel materials specifications are given in Table 4.4.

Table 4.4 Design parameters of Class E1 Stud connectors to European (EN), American (AWS), Japanese (JIS), Australian/New Zealand (AS/NZS), Chinese (GB) and Russian (GOST) specifications

Material specifications	Ultimate tensile strength, R_m (N/mm^2)
BS EN ISO 13918	400 ~ 780
AWS D1.1 (Type B)	450
JIS B 1198	400 ~ 550
AS/NZS 1554.2	410
GB/T 10433	400
GOST R ISO 898-1	400~1200

4.2.3.2 Class E1 Non-preloaded bolted assemblies

This section covers the design parameters for Class E1 Non-preloaded bolts and the recommended combinations of matching components in non-preloaded bolted assemblies. It covers ISO metric hexagon bolts, nuts and washers for non-preloaded (or bearing) bolted connections with bolts, plain washers with or without chamfers.

The design parameters for Class E1 Non-preloaded bolts corresponding to different bolt grades of various national steel materials specifications are given in Table 4.5.

Table 4.5a Design parameters of non-preloaded bolts to European (EN) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
4.6	240	400
8.8	640	800
10.9	900	1000
12.9	1080	1200

Table 4.5b Design parameters of Class E1 non-preloaded bolts to American (ASTM) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
A307 - Grade B	-	414
A325	660	830
A449 – Type 1	635	830
A490	940	1040

Table 4.5c Design parameters of Class E1 non-preloaded bolts to Japanese (JIS) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
4.8	-	420
8.8	-	800
10.9	-	1040
12.9	1080	1200

Table 4.5d Design parameters of Class E1 non-preloaded bolts to Australian/New Zealand (AS/NZ) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
4.6	240	400
8.8	640	800
10.9	900	1000
12.9	1080	1200

Table 4.5e Design parameters of Class E1 non-preloaded bolts to Chinese (GB) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
4.6	240	400
8.8	640	800
10.9	940	1040
12.9	1100	1220

Table 4.5f Design parameters of Class E1 non-preloaded bolts to Russian (GOST) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
5.6	300	500
5.8	400	500
8.8	640	800
10.9	900	1000
12.9	1080	1200

4.2.3.3 Class E1 Preloaded bolted assemblies

This section covers the design parameters for Class E1 Preloaded bolts and the recommended combinations of matching components in non-preloaded bolted assemblies. It covers ISO metric hexagon bolts, nuts and washers for preloaded bolted connections with bolts, plain washers with or without chamfers.

The design parameters of Class E1 Preloaded bolts corresponding to different bolt grades of various national steel materials specifications are given in Table 4.6.

Table 4.6a Design parameters of preloaded bolts to European (EN) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
8.8	640	800
10.9	900	1000
12.9	1080	1200

Table 4.6b Design parameters of Class E1 Preloaded bolts to American (ASTM) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
A325	660	830
A354 - Grade BC	685	795
A354 - Grade BD	900	1035
A490	940	1040

Table 4.6c Design parameters of Class E1 Preloaded bolts to Japanese (JIS) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
F8T	640	800
F10T	900	1000

Table 4.6d Design parameters of Class E1 Preloaded bolts to Australian/New Zealand (AS/NZS) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
8.8	640	800
10.9	900	1000
12.9	1080	1200

Table 4.6e Design parameters of Class E1 Preloaded bolts to Chinese (GB) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
8.8	640	800
10.9	940	1040
12.9	1100	1220

Table 4.6f Design parameters of Class E1 Preloaded bolts to Russian (GOST) specifications

Grade (Bolt marking)	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
10.9	900	1000
12.9	1080	1200

4.2.3.4 Class E1 Welding consumables

For design to EN 1993, the specified strengths, ductility and impact toughness of welding consumables should be at least equivalent to those specified for the parent metal. The design parameters corresponding to different weld grades of various national materials specifications are given in Table 4.7.

Table 4.7a Design parameters of welds made of European (EN) welding consumables

Grade	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
35	355	440
38	380	470
42	420	500
46	460	530
50	500	560

Table 4.7b Design parameters of Class E1 Welds made of American (AWS) welding consumables

Grade	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
E43xx	330	430
E49xx	400	490

Table 4.7c Design parameters of Class E1 Welds made of Japanese (JIS) welding consumables

Grade	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
E43xx	330	430
E49xx	390	480
E55xx	460	550
E57xx	490	570

Table 4.7d Design parameters of Class E1 Welds made of Australian/New Zealand (AS/NZ) welding consumables

Grade	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
E43xx	330	430
E49xx	390	480
E55xx	460	550
E57xx	490	570

Table 4.7e Design parameters of Class E1 Welds made of Chinese (GB) welding consumables

Grade	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
E43xx	330	430
E50xx	400	490
E55xx	460	550
E57xx	490	570

Table 4.7f Design parameters of Class E1 Welds made of Russian (GOST) welding consumables

Grade	Minimum yield strength R_e (N/mm^2)	Tensile strength R_m (N/mm^2)
Э42, Э42A	-	412
Э46, Э46A	-	451
Э50, Э50A	-	490
Э60	-	588
Э70	-	686

4.3 Design Parameters for Class E2 Steel Materials

This section presents the design guidance on Class E2 Steel materials which are manufactured in accordance with all the material requirements given in one of the Acceptable Materials Specifications, but without a certified Factory Production Control System according to European steel materials specifications. The corresponding material class factor γ_{MC} should be taken as 1.1.

4.3.1 Class E2 Structural steels

This section covers the design parameters for Class E2 Structural steels including

i) hot rolled plates, sections, hollow sections, sheet piles, solid bars,
ii) hot rolled strips for cold formed sections.

The design parameters for a proposed Class E2 Structural steel corresponding to different steel thicknesses given in a product standard are given in Table 4.8. It should be noted that R_{eHo} is the minimum yield strength according to the relevant product standard.

Table 4.8 Design parameters of Class E2 Structural steels

	For thickness (mm) less than or equal to					
	16	**40**	**63**	**80**	**100**	**150**
Minimum yield strength R_{eH} (N/mm^2)	R_{eHo}	0.95 R_{eHo}	0.92 R_{eHo}	0.90 R_{eHo}	0.85 R_{eHo}	0.80 R_{eHo}
Tensile strength R_m (N/mm^2)	R_{mo}	0.95 R_{mo}	0.92 R_{mo}	0.90 R_{mo}	0.86 R_{mo}	0.80 R_{mo}
* For rolled sections, used the specified thickness of the thickest element of the cross-section.						

Notes: R_{eHo} is the minimum yield strength according to the product standard, and
R_{mo} is the ultimate tensile strength according to the product standard.

4.3.2 Class E2 Thin gauge strips

The design parameters for Class E2 Thin gauge strips (hot rolled strips) for cold formed profiled sheeting given in a product standard (which is a national steel materials specification) should be computed using the following equations.

- Minimum yield strength

$$R_e = R_{eHo} \leq 550 \text{ N/mm}^2$$

- Tensile strength

$$R_m = R_{mo} \leq 600 \text{ N/mm}^2$$

where R_{eHo} is the minimum yield strength according to the product standard, and
R_{mo} is the ultimate tensile strength according to the product standard.

4.3.3 Class E2 Connection materials

This section covers the design parameters for Class E2 Connection materials including

i) Stud connectors
ii) Non-preloaded bolted assemblies
i) Preloaded bolted assemblies
ii) Welding consumables.

4.3.3.1 Class E2 Stud connectors

The design parameters for a proposed Class E2 Stud connector should be computed using the following equations.

- Minimum yield strength

$$R_e = R_{eo} \leq 275 \text{ N/mm}^2$$

- Tensile strength

$$R_m = R_{mo} \leq 450 \text{ N/mm}^2$$

where R_{eo} is the minimum yield strength according to the relevant product standard, and
R_{mo} is the ultimate tensile strength according to the relevant product standard.

4.3.3.2 Class E2 Non-preloaded bolted assemblies

This section covers the design parameters for Class E2 Non-preloaded bolts and the recommended combinations of matching components in non-preloaded bolted assemblies. It covers ISO metric hexagon bolts, nuts and washers for non-preloaded (or bearing) bolted connections with bolts, plain washers with or without chamfers.

The design parameters for a proposed Class E2 Non-preloaded bolt should be computed using the following equations:

- Minimum yield strength

$$R_e = 0.77\ R_{eo}$$

- Tensile strength

$$R_m = 0.77\ R_{mo}$$

where R_{eo} is the minimum yield strength according to the relevant product standard, and
R_{mo} is the ultimate tensile strength according to the relevant product standard.

4.3.3.3 Class E2 Preloaded bolted assemblies

This section covers the design parameters for Class E2 Preloaded bolts and the recommended combinations of matching components in preloaded bolted assemblies. It covers ISO metric hexagon bolts, nuts and washers for preloaded bolted connections with bolts, plain washers with or without chamfers.

The design parameters for a proposed Class E2 Preloaded bolt should be computed using the following equations:

- Minimum yield strength

  $R_e = \quad 0.77\ R_{eo}$

- Tensile strength

  $R_m = \quad 0.77\ R_{mo}$

where R_{eo} is the minimum yield strength according to the product standard of the proposed bolt, and

R_{mo} is the tensile strength according to the product standard of the proposed bolt.

4.3.3.4 Class E2 Welding consumables

The design parameters for a proposed Class E2 Welding consumable should be computed as follows:

- Minimum yield strength

  $R_e = \quad 0.80\ R_{eo}$

- Tensile strength

  $R_m = \quad 0.80\ R_{mo}$

where R_{eo} is the minimum yield strength according to the product standard of the proposed weld consumable, and

R_{mo} is the tensile strength according to the product standard of the proposed weld consumable.

Moreover, it should be noted that

i) the specified strengths of the welding consumables should be at least equal to 1.2 times of that specified for the parent metal, and

ii) the specified ductility and impact toughness of the welding consumables shall be at least equal to that specified for the parent metal.

4.4 Design Parameters for Class E3 Steel Materials

This section covers the use of Class E3 steel materials which are not in compliance with the requirements on neither material performance nor quality assurance. Hence, any steel material which cannot be demonstrated to be either Class E1 Steel Material or Class E2 Steel Material will be classified as Class E3 Steel Material; no additional material test is needed in general.

It should be noted that there are no Class 3 steel materials for thin gauge strips nor for connection materials.

4.4.1 Class E3 Structural steels

This section covers the design strengths of Class E3 Structural steels including

i) hot rolled plates, sections, hollow sections, sheet piles, solid bars, and
ii) hot rolled strips for cold formed sections.

Instead of giving the minimum yield strengths and tensile strengths of Class 3 Structural steels, the nominal values of yield strengths and of ultimate tensile strengths are given in Table 4.9.

Table 4.9 Design parameters of Class E3 Structural steels

Nominal value of yield strength, f_y **(N/mm²) for thickness[a] (mm) less than or equal to**					
16	**40**	**63**	**80**	**100**	**150**
170	160	155	150	145	135
a) For rolled sections, use the specified thickness of the thickest element of the cross-sections.					

It should be noted that the nominal values of ultimate tensile strength f_u should be computed using the following equation:

$$f_u = 1.1 f_y$$

where

f_y is the nominal value of yield strength given in Table 4.9.

References

BS EN 1993-1-1, Eurocode 3: Design of steel structures. General rules and rules for buildings. British Standards Institution, 2005.

BS EN 1994-1-1, Eurocode 4: Design of composite steel and concrete structures. General rules and rules for buildings. British Standards Institution, 2005.

Chabrolin, B. Partial safety factors for resistances of steel elements to EC3 and EC4 - Calibration for various steel products and failure criteria, Luxembourg Office for Official Publication of the European Communities 2002, ISBN: 92-894-3696-4.

Constructional Steel Design: World Developments. Dowling, P.J., Harding J.E., Bjorhovde R. and F. Martinez-Romero. Elsevier Science Publishers Ltd., 1992.

Chung, K.F., Harmonized member buckling design in Structural Eurocodes. Innovation in Construction, Research Journal 2014, Construction Industry Council, Hong Kong, 2014.

Code of Practice for Structural Use of Steel, Buildings Department, Government of Hong Kong SAR, Hong Kong, 2011 (2021 Edition).

Design Guide on Use of Alternative Steel Materials to BS 5950 (BC1: 2008). Building and Construction Authority, Singapore, 2008.

Design Guide on Use of Alternative Structural Steel to BS5950 and Eurocode 3 (BC1: 2012). Building and Construction Authority, Singapore, 2012.

Steel Designers' Manual. 7th Edition. Buick Davidson & Graham W. Owens. Steel Construction Institute, Wiley-Blackwell, 2012.

Structural Steel Selection Considerations: A Guide for Students, Educators, Designers, and Builders. American Society of Civil Engineers, 2000.

Willms R. High strength steels in steel construction: Application and processing. Proceedings of the 5th European Conference on Steel and Composite Structures, EUROSTEEL 2008, Graz, Page 1083-1088.

Ginzburg, Vladimir B. Metallurgical design of flat rolled steels. NY: Marcel Dekker, 2005.

William D. Callister, Jr., David G. Rethwisch. Materials science and engineering, 9th edition. NJ: Wiley, 2015.

Mandal, S. K. Steel metallurgy: properties, specifications and applications. NY: McGraw-Hill Education LLC., 2015.

Brandt, Daniel A., Warner, J.C. Metallurgy fundamentals. Ill.: Goodheart-Willcox, 2005.

Günther, Hans-Peter. Use and application of high-performance steels for steel structures. IABSE, 2005.

Appendices

A	List of acceptable steel materials		A1
	A.1	Acceptable British/European steel materials	A3
	A.2	Acceptable American steel materials	A27
	A.3	Acceptable Japanese steel materials	A49
	A.4	Acceptable Australian/New Zealand steel materials	A65
	A.5	Acceptable Chinese steel materials	A70
	A.6	Acceptable Russian steel materials	A89
B	List of reference standards		B1
	B.1	British/European standards	B2
	B.2	American standards	B8
	B.3	Japanese standards	B12
	B.4	Australian/New Zealand standards	B15
	B.5	Chinese standards	B17
	B.6	Russian specifications	B20
C	Quality control practices adopted by regulatory authorities		C1
	C.1	Quality control practice in Australia and New Zealand	C3
	C.2	Quality control practice in Hong Kong	C5
	C.3	Quality control practice in Macau	C7
	C.4	Quality control practice in Malaysia	C8
	C.5	Quality control practice in Singapore	C9
D	Worked Examples		D1
	D.1	Acceptance of British/European steel materials	D2
	D.2	Acceptance of American steel materials	D4
	D.3	Acceptance of Japanese steel materials	D7
	D.4	Acceptance of Australian/New Zealand steel materials	D10
	D.5	Acceptance of Chinese steel materials	D13
	D.6	Acceptance of Russian steel materials	D17
	D.7	Acceptance of Class E3 steel materials	D20

Appendix A Lists of acceptable steel materials

A.1 Acceptable British/European steel materials

A.2 Acceptable American steel materials

A.3 Acceptable Japanese steel materials

A.4 Acceptable Australian/New Zealand steel materials

A.5 Acceptable Chinese steel materials

A.6 Acceptable Russian steel materials

Appendix A Lists of Acceptable steel materials

This Appendix only covers acceptable steel materials manufactured to selected material standards as follows:

- British/European standards (BS EN),
- American standards (API, ASTM and AWS),
- Japanese standards (JIS),
- Australian/New Zealand standards (AS/NZS and AS),
- Chinese standards (GB), and
- Acceptable Russian steel materials (GOST).

It should be noted that reference should be made to the last version of the material standards.

NOTE Depending on the quality assurance provided by the manufacturer, materials in this appendix can be either Class 1 or Class 3.

A.1 Acceptable British/European steel materials

A.1.1 Acceptable British/European structural steel: plates

BS EN 10025-2: 2019 – Non-alloy Structural Steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P	S					
S235JR	3 ≤ t ≤ 16	0.17	0.035	0.035	0.35	235	360 ~ 510	26	≥ 27J @ 20°C
	16 < t ≤ 40	0.17				225			
	40 < t ≤ 63	0.20			0.38	215		25	
	63 < t ≤ 80					215		24	
	80 < t ≤ 100					215			
	100 < t ≤ 150					195	350 ~ 500	22	
S235J0	3 ≤ t ≤ 16	0.17	0.030	0.030	0.35	235	360 ~ 510	26	≥ 27J @ 0°C
	16 < t ≤ 40	0.17				225			
	40 < t ≤ 63	0.17			0.38	215		25	
	63 < t ≤ 80					215		24	
	80 < t ≤ 100					215			
	100 < t ≤ 150					195	350 ~ 500	22	
S235J2	3 ≤ t ≤ 16	0.17	0.025	0.025	0.35	235	360 ~ 510	26	≥ 27J @ -20°C
	16 < t ≤ 40	0.17				225			
	40 < t ≤ 63	0.17			0.38	215		25	
	63 < t ≤ 80					215		24	
	80 < t ≤ 100					215			
	100 < t ≤ 150					195	350 ~ 500	22	
S275JR	3 ≤ t ≤ 16	0.21	0.035	0.035	0.40	275	410 ~ 560	23	≥ 27J @ 20°C
	16 < t ≤ 40	0.21				265			
	40 < t ≤ 63	0.22			0.42	255		22	
	63 < t ≤ 80					245		21	
	80 < t ≤ 100					235			
	100 < t ≤ 150					225	400 ~ 540	19	
S275J0	3 ≤ t ≤ 16	0.18	0.030	0.030	0.40	275	410 ~ 560	23	≥ 27J @ 0°C
	16 < t ≤ 40	0.18				265			
	40 < t ≤ 63	0.18			0.42	255		22	
	63 < t ≤ 80					245		21	
	80 < t ≤ 100					235			
	100 < t ≤ 150					225	400 ~ 540	19	
S275J2	3 ≤ t ≤ 16	0.18	0.025	0.025	0.40	275	410 ~ 560	23	≥ 27J @ -20°C
	16 < t ≤ 40	0.18				265			
	40 < t ≤ 63	0.18			0.42	255		22	
	63 < t ≤ 80					245		21	
	80 < t ≤ 100					235			
	100 < t ≤ 150					225	400 ~ 540	19	

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%) C	P	S	Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness [b] (J)
	3 ≤ t ≤ 16	0.24			0.45	355		22	
	16 < t ≤ 40	0.24			0.45 [d]	345			
S355JR	40 < t ≤ 63		0.035	0.035		335	470 ~ 630	21	≥ 27J @ 20°C
	63 < t ≤ 80	0.24			0.47	325		20	
	80 < t ≤ 100					315			
	100 < t ≤ 150					295	450 ~ 600	18	
	3 ≤ t ≤ 16	0.20			0.45	355		22	
	16 < t ≤ 40	0.20 [d]			0.45 [d]	345			
S355J0	40 < t ≤ 63		0.030	0.030		335	470 ~ 630	21	≥ 27J @ 0°C
	63 < t ≤ 80	0.22			0.47	325		20	
	80 < t ≤ 100					315			
	100 < t ≤ 150					295	450 ~ 600	18	
	3 ≤ t ≤ 16	0.20			0.45	355		22	
	16 < t ≤ 40	0.20 [d]			0.45 [d]	345			
S355J2	40 < t ≤ 63		0.025	0.025		335	470 ~ 630	21	≥ 27J @ -20°C
	63 < t ≤ 80	0.22			0.47 *	325		20	
	80 < t ≤ 100					315			
	100 < t ≤ 150					295	450 ~ 600	18	
	3 ≤ t ≤ 16	0.20			0.45	355		22	
	16 < t ≤ 40	0.20 [d]			0.45 [d]	345			
S355K2	40 < t ≤ 63		0.025	0.025		335	470 ~ 630	21	≥ 40J @ -20°C [c]
	63 < t ≤ 80	0.22			0.47	325		20	
	80 < t ≤ 100					315			
	100 < t ≤ 150					295	450 ~ 600	18	

Note:
a. The direction parallel to the rolling direction applies. Transverse values are 2 % lower for thickness ≤ 100.
b. Minimum values of impact energy KV2 on longitudinal test pieces.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-10).
d. For nominal thickness > 30 mm: C = 0.22% max, Max. CEV = 0.47%.

BS EN 10025-3: 2019 - Normalized Rolled Weldable Fine Grain Structural Steels

Grade	Thickness (mm)	Chemical composition (%) C	P	S	Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness [b] (J)
	t ≤ 16					275			
	16 < t ≤ 40				0.40	265		24	
S275N	40 < t ≤ 63	0.18	0.030	0.025		255	370 ~ 510		≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	63 < t ≤ 80				0.40	245			
	80 < t ≤ 100					235		23	
	100 < t ≤ 150				0.42	225	350 ~ 480		
	t ≤ 16					275			
	16 < t ≤ 40				0.40	265		24	
S275NL	40 < t ≤ 63	0.16	0.025	0.020		255	370 ~ 510		≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	63 < t ≤ 80				0.40	245			
	80 < t ≤ 100					235		23	
	100 < t ≤ 150				0.42	225	350 ~ 480		

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness [b] (J)
		C	P	S					
S355N	t ≤ 16	0.20	0.030	0.025	0.43	355	470 ~ 630	22	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	16 < t ≤ 40					345			
	40 < t ≤ 63					335			
	63 < t ≤ 80				0.45	325		21	
	80 < t ≤ 100					315			
	100 < t ≤ 150				0.45	295	450 ~ 600		
S355NL	t ≤ 16	0.18	0.025	0.020	0.43	355	470 ~ 630	22	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	16 < t ≤ 40					345			
	40 < t ≤ 63					335			
	63 < t ≤ 80				0.45	325		21	
	80 < t ≤ 100					315			
	100 < t ≤ 150				0.45	295	450 ~ 600		
S420N	t ≤ 16	0.20	0.030	0.025	0.48	420	520 ~ 680	19	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	16 < t ≤ 40					400			
	40 < t ≤ 63					390			
	63 < t ≤ 80				0.50	370		18	
	80 < t ≤ 100					360			
	100 < t ≤ 150				0.52	340	500 ~ 650		
S420NL	t ≤ 16	0.20	0.025	0.020	0.48	420	520 ~ 680	19	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	16 < t ≤ 40					400			
	40 < t ≤ 63					390			
	63 < t ≤ 80				0.50	370		18	
	80 < t ≤ 100					360			
	100 < t ≤ 150				0.52	340	500 ~ 650		
S460N	t ≤ 16	0.20	0.030	0.025	0.53	460	540 ~ 720	17	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	16 < t ≤ 40					440			
	40 < t ≤ 63					430			
	63 < t ≤ 80				0.54	410		17	
	80 < t ≤ 100					400			
	100 < t ≤ 150				0.55	380	530 ~ 710		
S460NL	t ≤ 16	0.20	0.025	0.020	0.53	460	540 ~ 720	17	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	16 < t ≤ 40					440			
	40 < t ≤ 63					430			
	63 < t ≤ 80				0.54	410		17	
	80 < t ≤ 100					400			
	100 < t ≤ 150				0.55	380	530 ~ 710		

Note: b. Minimum values of impact energy KV2 on longitudinal test pieces.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-10).

BS EN 10025-4: 2019 - Thermo-mechanical Rolled Weldable Fine Grain Structural Steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness [b] (J)
		C	P	S					
S275M	t ≤ 16	0.13	0.025	0.025	0.34	275	370 ~ 530	24	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	16 < t ≤ 40				0.34	265			
	40 < t ≤ 63				0.35	255	360 ~ 520		
	63 < t ≤ 80				0.38	245	350 ~ 510		
	80 < t ≤ 100					245	350 ~ 510		
	100 < t ≤ 150					240	350 ~ 510		
S275ML	t ≤ 16	0.13	0.025	0.020	0.34	275	370 ~ 530	24	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	16 < t ≤ 40				0.34	265			
	40 < t ≤ 63				0.35	255	360 ~ 520		
	63 < t ≤ 80				0.38	245	350 ~ 510		
	80 < t ≤ 100					245	350 ~ 510		
	100 < t ≤ 150					240	350 ~ 510		
S355M	t ≤ 16	0.14	0.025	0.025	0.39	355	470 ~ 630	22	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	16 < t ≤ 40				0.39	345			
	40 < t ≤ 63				0.40	335	450 ~ 610		
	63 < t ≤ 80				0.45	325	440 ~ 600		
	80 < t ≤ 100					325	440 ~ 600		
	100 < t ≤ 150					320	430 ~ 590		
S355ML	t ≤ 16	0.14	0.025	0.020	0.39	355	470 ~ 630	22	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	16 < t ≤ 40				0.39	345			
	40 < t ≤ 63				0.40	335	450 ~ 610		
	63 < t ≤ 80				0.45	325	440 ~ 600		
	80 < t ≤ 100				0.45	325	440 ~ 600		
	100 < t ≤ 150				0.45	320	430 ~ 590		
S420M	t ≤ 16	0.16	0.030	0.025	0.43	420	520 ~ 680	19	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	16 < t ≤ 40				0.45	400			
	40 < t ≤ 63				0.46	390	500 ~ 660		
	63 < t ≤ 80				0.47	380	480 ~ 640		
	80 < t ≤ 100					370	470 ~ 630		
	100 < t ≤ 150					365	460 ~ 620		
S420ML	t ≤ 16	0.16	0.025	0.020	0.43	420	520 ~ 680	19	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	16 < t ≤ 40				0.45	400			
	40 < t ≤ 63				0.46	390	500 ~ 660		
	63 < t ≤ 80				0.47	380	480 ~ 640		
	80 < t ≤ 100					370	470 ~ 630		
	100 < t ≤ 150					365	460 ~ 620		
S460M	t ≤ 16	0.16	0.030	0.025	0.45	460	540 ~ 720	17	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	16 < t ≤ 40				0.46	440			
	40 < t ≤ 63				0.47	430	530 ~ 710		
	63 < t ≤ 80				0.48	410	510 ~ 690		
	80 < t ≤ 100					400	500 ~ 680		
	100 < t ≤ 150					385	480 ~ 640		

(To be continued)

(Continued)

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness [b] (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td rowspan="6">S460ML</td><td>t ≤ 16</td><td rowspan="6">0.16</td><td rowspan="6">0.025</td><td rowspan="6">0.020</td><td>0.45</td><td>460</td><td rowspan="2">540 ~ 720</td><td rowspan="6">17</td><td rowspan="6">≥ 63J @ 20°C
≥ 55J @ 0°C
≥ 51J @ -10°C
≥ 47J @ -20°C
≥ 40J @ -30°C
≥ 31J @ -40°C
≥ 27J @ -50°C</td></tr>
<tr><td>16 < t ≤ 40</td><td>0.46</td><td>440</td></tr>
<tr><td>40 < t ≤ 63</td><td>0.47</td><td>430</td><td>530 ~ 710</td></tr>
<tr><td>63 < t ≤ 80</td><td rowspan="3">0.48</td><td>410</td><td>510 ~ 690</td></tr>
<tr><td>80 < t ≤ 100</td><td>400</td><td>500 ~ 680</td></tr>
<tr><td>100 < t ≤ 150</td><td>385</td><td>480 ~ 640</td></tr>
<tr><td rowspan="7">S500M</td><td>t ≤ 16</td><td rowspan="7">0.16</td><td rowspan="7">0.025</td><td rowspan="7">0.020</td><td>0.47</td><td>500</td><td rowspan="3">580 ~ 760</td><td rowspan="7">15</td><td rowspan="7">≥ 55J @ 20°C
≥ 47J @ 0°C
≥ 43J @ -10°C
≥ 40J @ -20°C [c]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>16 < t ≤ 40</td><td>0.47</td><td>480</td></tr>
<tr><td>40 < t ≤ 63</td><td>0.47</td><td>460</td><td>580 ~ 760</td></tr>
<tr><td>63 < t ≤ 80</td><td rowspan="3">0.48</td><td>450</td><td>580 ~ 760</td></tr>
<tr><td>80 < t ≤ 100</td><td>450</td><td>560 ~ 750</td></tr>
<tr><td>100 < t ≤ 150</td><td>450</td><td>560 ~ 750</td></tr>
<tr><td rowspan="6">S500ML</td><td>t ≤ 16</td><td rowspan="6">0.16</td><td rowspan="6">0.025</td><td rowspan="6">0.020</td><td>0.47</td><td>500</td><td rowspan="2">580 ~ 760</td><td rowspan="6">15</td><td rowspan="6">≥ 63J @ 20°C
≥ 55J @ 0°C
≥ 51J @ -10°C
≥ 47J @ -20°C
≥ 40J @ -30°C
≥ 31J @ -40°C
≥ 27J @ -50°C</td></tr>
<tr><td>16 < t ≤ 40</td><td>0.47</td><td>480</td></tr>
<tr><td>40 < t ≤ 63</td><td>0.47</td><td>460</td><td>580 ~ 760</td></tr>
<tr><td>63 < t ≤ 80</td><td rowspan="3">0.48</td><td>450</td><td>580 ~ 760</td></tr>
<tr><td>80 < t ≤ 100</td><td>450</td><td>560 ~ 750</td></tr>
<tr><td>100 < t ≤ 150</td><td>450</td><td>560 ~ 750</td></tr>
</table>

Note: b. Minimum values of impact energy KV2 on longitudinal test pieces.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-10).

BS EN 10025-5: 2019 - Structural Steels with Improved Atmospheric Corrosion Resistance

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L [a] (%)</th><th rowspan="2">Impact toughness [b] (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>S235J0W</td><td>3 ≤ t ≤ 12</td><td>0.13</td><td>max. 0.035</td><td>0.035</td><td>0.44</td><td>225</td><td>360 ~ 510</td><td>26</td><td>≥ 27J @ 0°C</td></tr>
<tr><td>S235J2W</td><td>3 ≤ t ≤ 12</td><td>0.13</td><td>max. 0.035</td><td>0.030</td><td>0.44</td><td>225</td><td>360 ~ 510</td><td>26</td><td>≥ 27J @ -20°C</td></tr>
<tr><td rowspan="2">S355J0WP</td><td>3 ≤ t ≤ 16</td><td rowspan="2">0.12</td><td rowspan="2">0.060 ~ 0.15</td><td rowspan="2">0.035</td><td rowspan="2">0.52</td><td>355</td><td rowspan="2">470 ~ 630 [d]</td><td rowspan="2">22</td><td rowspan="2">≥ 27J @ 0°C</td></tr>
<tr><td>16 < t ≤ 40</td><td>345</td></tr>
<tr><td rowspan="2">S355J2WP</td><td>3 ≤ t ≤ 16</td><td rowspan="2">0.12</td><td rowspan="2">0.060 ~ 0.15</td><td rowspan="2">0.030</td><td rowspan="2">0.52</td><td>355</td><td rowspan="2">470 ~ 630</td><td rowspan="2">20</td><td rowspan="2">≥ 27J @ -20°C</td></tr>
<tr><td>16 < t ≤ 40</td><td>345</td></tr>
<tr><td>S355J0W</td><td>3 ≤ t ≤ 12</td><td>0.16</td><td>max. 0.035</td><td>0.035</td><td>0.52</td><td>355</td><td>470 ~ 630</td><td>22</td><td>≥ 27J @ 0°C</td></tr>
<tr><td>S355J2W</td><td>3 ≤ t ≤ 12</td><td>0.16</td><td>max. 0.030</td><td>0.030</td><td>0.52</td><td>355</td><td>470 ~ 630</td><td>22</td><td>≥ 27J @ -20°C</td></tr>
<tr><td>S355K2W</td><td>3 ≤ t ≤ 12</td><td>0.16</td><td>max. 0.030</td><td>0.030</td><td>0.52</td><td>355</td><td>470 ~ 630</td><td>22</td><td>≥ 40J @ -20°C [c]</td></tr>
<tr><td>S355J4W</td><td>3 ≤ t ≤ 12</td><td>0.16</td><td>max. 0.030</td><td>0.025</td><td>0.52</td><td>355</td><td>470 ~ 630</td><td>22</td><td>≥ 27J @ -40°C</td></tr>
<tr><td>S355J5W</td><td>3 ≤ t ≤ 12</td><td>0.16</td><td>max. 0.030</td><td>0.025</td><td>0.52</td><td>355</td><td>470 ~ 630</td><td>22</td><td>≥ 27J @ -50°C</td></tr>
<tr><td>S420J0W</td><td>3 ≤ t ≤ 12</td><td>0.20</td><td>max. 0.035</td><td>0.035</td><td>0.52</td><td>420</td><td>500 ~ 660</td><td>19</td><td>≥ 27J @ 0°C</td></tr>
<tr><td>S420J2W</td><td>3 ≤ t ≤ 12</td><td>0.20</td><td>max. 0.030</td><td>0.030</td><td>0.52</td><td>420</td><td>500 ~ 660</td><td>19</td><td>≥ 27J @ -20°C</td></tr>
<tr><td>S420K2W</td><td>3 ≤ t ≤ 12</td><td>0.20</td><td>max. 0.030</td><td>0.030</td><td>0.52</td><td>420</td><td>500 ~ 660</td><td>19</td><td>≥ 40J @ -20°C</td></tr>
<tr><td>S420J4W</td><td>3 ≤ t ≤ 12</td><td>0.20</td><td>max. 0.030</td><td>0.025</td><td>0.52</td><td>420</td><td>500 ~ 660</td><td>19</td><td>≥ 27J @ -40°C</td></tr>
<tr><td>S420J5W</td><td>3 ≤ t ≤ 12</td><td>0.20</td><td>max. 0.030</td><td>0.025</td><td>0.52</td><td>420</td><td>500 ~ 660</td><td>19</td><td>≥ 27J @ -50°C</td></tr>
<tr><td>S460J0W</td><td>3 ≤ t ≤ 12</td><td>0.20</td><td>max. 0.035</td><td>0.035</td><td>0.52</td><td>460</td><td>530 ~ 710</td><td>17</td><td>≥ 27J @ 0°C</td></tr>
</table>

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P	S					
S460J2W	3 ≤ t ≤ 12	0.20	max. 0.030	0.030	0.52	460	530 ~ 710	17	≥ 27J @ -20°C
S460K2W	3 ≤ t ≤ 12	0.20	max. 0.030	0.030	0.52	460	530 ~ 710	17	≥ 40J @ -20°C
S460J4W	3 ≤ t ≤ 12	0.20	max. 0.030	0.025	0.52	460	530 ~ 710	17	≥ 27J @ -40°C
S460J5W	3 ≤ t ≤ 12	0.20	max. 0.030	0.025	0.52	460	530 ~ 710	17	≥ 27J @ -50°C

Note: a. Longitudinal values.
b. Minimum values of impact energy KV2 on longitudinal test pieces.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-10).
d. applicable up to 12mm.

BS EN 10025-6: 2019 – High Strength Structural Steels in the Quenched and Tempered Condition

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness [b] (J)
		C	P	S					
S460Q	3 ≤ t ≤ 50	0.20	0.025	0.015	0.47	460	550 ~ 720	17	≥ 40J @ 0°C ≥ 30J @ -20°C
	50 < t ≤ 100				0.48	440			
	100 < t ≤ 150				0.50	400	500 ~ 670		
S460QL	3 ≤ t ≤ 50	0.20	0.020	0.010	0.47	460	550 ~ 720	17	≥ 50J @ 0°C ≥ 40J @ -20°C ≥ 30J @ -40°C
	50 < t ≤ 100				0.48	440			
	100 < t ≤ 150				0.50	400	500 ~ 670		
S460QL1	3 ≤ t ≤ 50	0.20	0.020	0.010	0.47	460	550 ~ 720	17	≥ 60J @ 0°C ≥ 50J @ -20°C ≥ 40J @ -40°C ≥ 30J @ -60°C
	50 < t ≤ 100				0.48	440			
	100 < t ≤ 150				0.50	400	500 ~ 670		
S500Q	3 ≤ t ≤ 50	0.20	0.025	0.015	0.47	500	590 ~ 770	17	≥ 40J @ 0°C ≥ 30J @ -20°C
	50 < t ≤ 100				0.70	480			
	100 < t ≤ 150				0.70	440	540 ~ 720		
S500QL	3 ≤ t ≤ 50	0.20	0.020	0.010	0.47	500	590 ~ 770	17	≥ 50J @ 0°C ≥ 40J @ -20°C ≥ 30J @ -40°C
	50 < t ≤ 100				0.70	480			
	100 < t ≤ 150				0.70	440	540 ~ 720		
S500QL1	3 ≤ t ≤ 50	0.20	0.020	0.010	0.47	500	590 ~ 770	17	≥ 60J @ 0°C ≥ 50J @ -20°C ≥ 40J @ -40°C ≥ 30J @ -60°C
	50 < t ≤ 100				0.70	480			
	100 < t ≤ 150				0.70	440	540 ~ 720		
S550Q	3 ≤ t ≤ 50	0.20	0.025	0.015	0.65	550	640 ~ 820	16	≥ 40J @ 0°C ≥ 30J @ -20°C
	50 < t ≤ 100				0.77	530			
	100 < t ≤ 150				0.83	490	590 ~ 770		
S550QL	3 ≤ t ≤ 50	0.20	0.020	0.010	0.65	550	640 ~ 820	16	≥ 50J @ 0°C ≥ 40J @ -20°C ≥ 30J @ -40°C
	50 < t ≤ 100				0.77	530			
	100 < t ≤ 150				0.83	490	590 ~ 770		
S550QL1	3 ≤ t ≤ 50	0.20	0.020	0.010	0.65	550	640 ~ 820	16	≥ 60J @ 0°C ≥ 50J @ -20°C ≥ 40 @ -40°C ≥ 30J @ -60°C
	50 < t ≤ 100				0.77	530			
	100 < t ≤ 150				0.83	490	590 ~ 770		
S620Q	3 ≤ t ≤ 50	0.20	0.025	0.015	0.65	620	700 ~ 890	15	≥ 40J @ 0°C ≥ 30J @ -20°C
	50 < t ≤ 100				0.77	580			
	100 < t ≤ 150				0.83	560	650 ~ 830		

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness [b] (J)
		C	P	S					
S620QL	3 ≤ t ≤ 50	0.20	0.020	0.010	0.65	620	700 ~ 890	15	≥ 50J @ 0ºC ≥ 40J @ -20ºC ≥ 30J @ -40ºC
	50 < t ≤ 100				0.77	580			
	100 < t ≤ 150				0.83	560	650 ~ 830		
S620QL1	3 ≤ t ≤ 50	0.20	0.020	0.010	0.65	620	700 ~ 890	15	≥ 60J @ 0ºC ≥ 50J @ -20ºC ≥ 40J @ -40ºC ≥ 30J @ -60ºC
	50 < t ≤ 100				0.77	580			
	100 < t ≤ 150				0.83	560	650 ~ 830		
S690Q	3 ≤ t ≤ 50	0.20	0.025	0.015	0.65	690	770 ~ 940	14	≥ 40J @ 0ºC ≥ 30J @ -20ºC
	50 < t ≤ 100				0.77	650	760 ~ 930		
	100 < t ≤ 150				0.83	630	710 ~ 900		
S690QL	3 ≤ t ≤ 50	0.20	0.020	0.010	0.65	690	770 ~ 940	14	≥ 50J @ 0ºC ≥ 40J @ -20ºC ≥ 30J @ -40ºC
	50 < t ≤ 100				0.77	650	760 ~ 930		
	100 < t ≤ 150				0.83	630	710 ~ 900		
S690QL1	3 ≤ t ≤ 50	0.20	0.020	0.010	0.65	690	770 ~ 940	14	≥ 60J @ 0ºC ≥ 50J @ -20ºC ≥ 40J @ -40ºC ≥ 30J @ -60ºC
	50 < t ≤ 100				0.77	650	760 ~ 930		
	100 < t ≤ 150				0.83	630	710 ~ 900		

Note: b. Minimum values of impact energy KV2 on longitudinal test pieces.

with dimensional and/or mass tolerances in accordance with:-

BS EN 10029:2010 – Tolerance for hot rolled steel plate over 3mm thick

Nominal thickness t (mm)	Tolerances on the nominal thickness							
	Class A		Class B		Class C		Class D	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
$8 \leq t \leq 15$	-0.5	+0.9	-0.3	+1.1	0.0	+1.4	-0.7	+0.7
$15 < t \leq 25$	-0.6	+1.0	-0.3	+1.3	0.0	+1.6	-0.8	+0.8
$25 < t \leq 40$	-0.7	+1.3	-0.3	+1.7	0.0	+2.0	-1.0	+1.0
$40 < t \leq 80$	-0.9	+1.7	-0.3	+2.3	0.0	+2.6	-1.3	+1.3
$80 < t \leq 150$	-1.1	+2.1	-0.3	+2.9	0.0	+3.2	-1.6	+1.6

BS EN 10051:2010 – Tolerance for continuously hot-rolled strip and sheet / plate cut from wide strip of non-alloy and alloy steels

Nominal thickness t (mm)	Minimum yield strength R_e (N/mm^2)	Tolerances for a nominal width w			
		$w \leq 1200$	$1200 < w \leq 1500$	$1500 < w \leq 1800$	$w > 1800$
$8.0 \leq t \leq 10.0$	$R_e \leq 300$ (Category A)	± 0.32	± 0.33	± 0.34	± 0.40
$10.0 < t \leq 12.5$		± 0.35	± 0.36	± 0.37	± 0.43
$12.5 < t \leq 15.0$		± 0.37	± 0.38	± 0.40	± 0.46
$15.0 < t \leq 25.0$		± 0.40	± 0.42	± 0.47	± 0.50
$8.0 \leq t \leq 10.0$	$300 \leq R_e \leq 360$ (Category B)	± 0.37	± 0.38	± 0.39	± 0.46
$10.0 < t \leq 12.5$		± 0.40	± 0.41	± 0.43	± 0.49
$12.5 < t \leq 15.0$		± 0.43	± 0.44	± 0.46	± 0.53
$15.0 < t \leq 25.0$		± 0.46	± 0.48	± 0.52	± 0.58
$8.0 \leq t \leq 10.0$	$360 \leq R_e \leq 420$ (Category C)	± 0.42	± 0.43	± 0.44	± 0.52
$10.0 < t \leq 12.5$		± 0.46	± 0.47	± 0.48	± 0.56
$12.5 < t \leq 15.0$		± 0.48	± 0.49	± 0.52	± 0.60
$15.0 < t \leq 25.0$		± 0.52	± 0.55	± 0.59	± 0.65

A.1.2 Acceptable British/European structural steel: sections

BS EN 10025-2: 2019 - Non-alloy Structural Steel [f]

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P [e]	S [e]					
S235JR	3 ≤ t ≤ 63	*Refer to BS EN 10025-2 in Section A.1.1*							
S235J0	3 ≤ t ≤ 63								
S235J2	3 ≤ t ≤ 63								
S275JR	3 ≤ t ≤ 63								
S275J0	3 ≤ t ≤ 63								
S275J2	3 ≤ t ≤ 63								
S355JR	3 ≤ t ≤ 63								
S355J0	3 ≤ t ≤ 63								
S355J2	3 ≤ t ≤ 63								
S355K2	3 ≤ t ≤ 63								
S460JR	3 ≤ t ≤ 16	0.20	0.030	0.030	0.47	460	550 ~ 720	17	≥ 27J @ 20°C
	16 < t ≤ 40	0.20 [d]			0.47 [d]	440			
	40 < t ≤ 63	0.22			0.49	420			
S460J0[j]	3 ≤ t ≤ 16	0.20	0.030	0.030	0.47	460	550 ~ 720	17	≥ 27J @ 0°C
	16 < t ≤ 40	0.20 [d]			0.47 [d]	440			
	40 < t ≤ 63	0.22			0.49	420			
S460J2[j]	3 ≤ t ≤ 16	0.20	0.030	0.030	0.47	460	550 ~ 720	17	≥ 27J @ -20°C
	16 < t ≤ 40	0.20 [d]			0.47 [d]	440			
	40 < t ≤ 63	0.22			0.49	420			
S460K2	3 ≤ t ≤ 16	0.20	0.030	0.030	0.47	460	550 ~ 720	17	≥ 40J @ 20°C
	16 < t ≤ 40	0.20 [d]			0.47 [d]	440			
	40 < t ≤ 63	0.22			0.49	420			
S500J0	3 ≤ t ≤ 16	0.20	0.030	0.030	0.49	500	580 ~ 760	15	≥ 27-J @ 0°C
	16 < t ≤ 40	0.20			0.49	480			
	40 < t ≤ 63	0.22			0.49	460			

Note: a. The direction parallel to the rolling direction applies.
b. Minimum values of impact energy KV2 on longitudinal test pieces.
d. For nominal thickness > 30 mm: C = 0.22% max, Max. CEV = 0.49%.
e. For long products the P and S content can be 0.005% higher.
f. This document does not apply to structural hollow sections and tubes.

BS EN 10025-3: 2019 - Normalized Rolled Weldable Fine Grain Structural Steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P [e]	S [e]					
S275N	t ≤ 63	*Refer to BS EN 10025-3 in Section A.1.1*							
S275NL	t ≤ 63								
S355N	t ≤ 63								
S355NL	t ≤ 63								
S420N	t ≤ 63								
S420NL	t ≤ 63								
S460N	t ≤ 63								
S460NL	t ≤ 63								

Note: e. For long products the P and S content can be 0.005% higher.

BS EN 10025-4: 2019 - Thermo-mechanical Rolled Weldable Fine Grain Structural Steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P [e]	S [e]					
S275M	t ≤ 63	0.15	*Refer to BS EN 10025-4 in Section A.1.1*						
S275ML	t ≤ 63	0.15							
S355M	t ≤ 63	0.16							
S355ML	t ≤ 63	0.16							
S420M	t ≤ 63	0.18							
S420ML	t ≤ 63	0.18							
S460M	t ≤ 63	0.18							
S460ML	t ≤ 63	0.18							
S500M	t ≤ 63	0.18							
S500ML	t ≤ 63	0.18							

Note: e. For long products the P and S content can be 0.005% higher.

BS EN 10025-5: 2019 - Structural Steels with Improved Atmospheric Corrosion Resistance

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P [e]	S [e]					
S355J0WP	3 ≤ t ≤ 40	*Refer to BS EN 10025-5 in Section A.1.1*							
S355J2WP	t ≤ 40								
S355J5W	3 ≤ t ≤ 16	0.16	max. 0.030	0.025	0.52	355	470 ~ 630	22	≥ 27J @ -50°C
	16 < t ≤ 40					345			
	40 < t ≤ 63					335		21	
S420J4W	3 ≤ t ≤ 16	0.20	max. 0.030	0.025	0.52	420	500 ~ 660	19	≥ 27J @ -40°C
	16 < t ≤ 40					400			
	40 < t ≤ 63					390		18	
S420J5W	3 ≤ t ≤ 16	0.20	max. 0.030	0.025	0.52	420	500 ~ 660	19	≥ 27J @ -50°C
	16 < t ≤ 40					400			
	40 < t ≤ 63					390		18	
S460J4W	3 ≤ t ≤ 16	0.20	max. 0.030	0.025	0.52	460	530 ~ 710	17	≥ 27J @ -40°C
	16 < t ≤ 40					440			
	40 < t ≤ 63					430		16	
S460J5W	3 ≤ t ≤ 16	0.20	max. 0.030	0.025	0.52	460	530 ~ 710	17	≥ 27J @ -50°C
	16 < t ≤ 40					440			
	40 < t ≤ 63					430		16	

Note: a. Longitudinal values.
b. Minimum values of impact energy KV2 on longitudinal test pieces.
e. For long products the P and S content can be 0.005% higher.

with dimensional and/or mass tolerances in accordance with:-

- BS EN 10024
- BS EN 10034
- BS EN 10055
- BS EN 10056-2
- BS EN 10279

A.1.3 Acceptable British/European structural steel: hollow sections

BS EN 10210-1: 2006 - Hot finished non-alloy and fine grain steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [a] (%)	Impact toughness (J)
		C	P	S					
S235JRH	3 ≤ t ≤ 16	0.170	0.040	0.040	0.37	235	360 ~ 510	26	≥ 27J @ 20ºC
	16 < t ≤ 40				0.39	225			
	40 < t ≤ 63	0.200			0.41 [b]	215		25	
	63 < t ≤ 80				0.44	215		24	
S275J0H	3 ≤ t ≤ 16	0.200	0.035	0.035	0.41	275	410 ~ 560	23	≥ 27J @ 0ºC
	16 < t ≤ 40				0.43	265			
	40 < t ≤ 63	0.220			0.45 [b]	255		22	
	63 < t ≤ 80				0.48	245		21	
S275J2H	3 ≤ t ≤ 16	0.200	0.030	0.030	0.41	275	410 ~ 560	23	≥ 27J @-20ºC
	16 < t ≤ 40				0.43	265			
	40 < t ≤ 63	0.220			0.45 [b]	255		22	
	63 < t ≤ 80				0.48	245		21	
S275NH	3 ≤ t ≤ 16	0.200	0.035	0.030	0.40	275	370 ~ 510	24	≥ 40J @-20ºC [c]
	16 < t ≤ 40				0.40	265			
	40 < t ≤ 65					255			
S275NLH	3 ≤ t ≤ 16	0.200	0.030	0.025	0.40	275	370 ~ 510	24	≥ 27J @-50ºC
	16 < t ≤ 40				0.40	265			
	40 < t ≤ 65					255			
S355J0H	3 ≤ t ≤ 16	0.220	0.035	0.035	0.45	355	470 ~ 630	22	≥ 27J @ 0ºC
	16 < t ≤ 40				0.47	345			
	40 < t ≤ 63	0.220			0.50 [b]	335		21	
	63 < t ≤ 80				0.53	325		20	
S355J2H	3 ≤ t ≤ 16	0.220	0.030	0.030	0.45	355	470 ~ 630	22	≥ 27J @-20ºC
	16 < t ≤ 40				0.47	345			
	40 < t ≤ 63	0.220			0.50 [b]	335		21	
	63 < t ≤ 80				0.53	325		20	
S355K2H	3 ≤ t ≤ 16	0.220	0.030	0.030	0.45	355	470 ~ 630	22	≥ 40J @-20ºC [c]
	16 < t ≤ 40				0.47	345			
	40 < t ≤ 63	0.220			0.50 [b]	335		21	
	63 < t ≤ 80				0.53	325		20	
S355NH	3 ≤ t ≤ 16	0.200	0.035	0.030	0.43	355	470 ~ 630	22	≥ 40J @-20ºC [c]
	16 < t ≤ 40				0.45	345			
	40 < t ≤ 65					335			
S355NLH	3 ≤ t ≤ 16	0.180	0.030	0.025	0.43	355	470 ~ 630	22	≥ 27J @-50ºC
	16 < t ≤ 40				0.45	345			
	40 < t ≤ 65					335			
S420NH	3 ≤ t ≤ 16	0.220	0.035	0.030	0.50	420	520 ~ 680	19	≥ 40J @-20ºC [c]
	16 < t ≤ 40				0.52	400			
	40 < t ≤ 65					390			

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness (J)
		C	P	S					
S420NH	3 ≤ t ≤ 16	0.220	0.030	0.025	0.50	420	520 ~ 680	19	≥ 27J @-50°C
	16 < t ≤ 40				0.52	400			
	40 < t ≤ 65					390			
S460NH	3 ≤ t ≤ 16	0.220	0.035	0.030	0.53	460	540 ~ 720	17	≥ 40J @-20°C [c]
	16 < t ≤ 40				0.55	440			
	40 < t ≤ 65					430			
S460NLH	3 ≤ t ≤ 16	0.220	0.030	0.025	0.53	460	540 ~ 720	17	≥ 27J @-50°C
	16 < t ≤ 40				0.55	440			
	40 < t ≤ 65					430			

Note: a. Longitudinal values. Transverse values are 2 % lower.
b. The value of Max. CEV apply for normal thickness ≤ 65 mm.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-1).

BS EN 10219-1: 2006 – Cold formed welded structural hollow sections of non-alloy and fine grain steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
S235JRH	3 ≤ t ≤ 16	0.17	0.040	0.040	0.35	235	360 ~ 510	24 [a]	≥ 27J @ 20°C
	16 < t ≤ 40					225			
S275J0H	3 ≤ t ≤ 16	0.20	0.035	0.035	0.40	275	410 ~ 560	20 [b]	≥ 27J @ 0°C
	16 < t ≤ 40					265			
S275J2H	3 ≤ t ≤ 16	0.20	0.030	0.030	0.40	275	410 ~ 560	20 [b]	≥ 27J @ -20°C
	16 < t ≤ 40					265			
S275NH	3 ≤ t ≤ 16	0.20	0.035	0.030	0.40	275	370 ~ 510	24	≥ 40J @ -20°C [c]
	16 < t ≤ 40					265			
S275NLH	3 ≤ t ≤ 16	0.20	0.030	0.025	0.40	275	370 ~ 510	24	≥ 27J @ -50°C
	16 < t ≤ 40					265			
S275MH	3 ≤ t ≤ 16	0.13	0.035	0.030	0.34	275	360 ~ 510	24	≥ 40J @ -20°C [c]
	16 < t ≤ 40					265			
S275MLH	3 ≤ t ≤ 16	0.13	0.030	0.025	0.34	275	360 ~ 510	24	≥ 27J @ -50°C
	16 < t ≤ 40					265			
S355J0H	3 ≤ t ≤ 16	0.22	0.035	0.035	0.45	355	470 ~ 630	20 [b]	≥ 27J @ 0°C
	16 < t ≤ 40					345			
S355J2H	3 ≤ t ≤ 16	0.22	0.030	0.030	0.45	355	470 ~ 630	20 [b]	≥ 27J @ -20°C
	16 < t ≤ 40					345			
S355K2H	3 ≤ t ≤ 16	0.22	0.030	0.030	0.45	355	470 ~ 630	20 [b]	≥ 40J @ -20°C [c]
	16 < t ≤ 40					345			
S355NH	3 ≤ t ≤ 16	0.20	0.035	0.030	0.43	355	470 ~ 630	22	≥ 40J @ -20°C [c]
	16 < t ≤ 40					345			
S355NLH	3 ≤ t ≤ 16	0.18	0.030	0.025	0.43	355	470 ~ 630	22	≥ 27J @ -50°C
	16 < t ≤ 40					345			

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
S355MH	3 ≤ t ≤ 16	0.14	0.035	0.030	0.39	355	450 ~ 610	22	≥ 40J @ -20°C [c]
	16 < t ≤ 40					345			
S355MLH	3 ≤ t ≤ 16	0.14	0.030	0.025	0.39	355	450 ~ 610	22	≥ 27J @ -50°C
	16 < t ≤ 40					345			
S420MH	3 ≤ t ≤ 16	0.16	0.035	0.030	0.43	420	500 ~ 660	19	≥ 40J @ -20°C [c]
	16 < t ≤ 40					400			
S420MLH	3 ≤ t ≤ 16	0.16	0.030	0.025	0.43	420	500 ~ 660	19	≥ 27J @ -50 °C
	16 < t ≤ 40					400			
S460NH	3 ≤ t ≤ 16	0.20	0.035	0.030	0.53	460	540 ~ 720	17	≥ 40J @ -20°C [c]
	16 < t ≤ 40					440			
S460NLH	3 ≤ t ≤ 16	0.20	0.030	0.025	0.53	460	540 ~ 720	17	≥ 27J @ -50°C
	16 < t ≤ 40					440			
S460MH	3 ≤ t ≤ 16	0.16	0.035	0.030	0.46	460	530 ~ 720	17	≥ 40J @ -20°C [c]
	16 < t ≤ 40					440			
S460MLH	3 ≤ t ≤ 16	0.16	0.030	0.025	0.46	460	530 ~ 720	17	≥ 27J @ -50°C
	16 < t ≤ 40					440			

Note:
a. For thicknesses > 3 mm and section sizes D/T < 15 (round) and (B+H)/2T < 12,5 (square and rectangular) the minimum elongation is reduced by 2.
b. For section sizes D/T < 15 (circular) and (B+H)/2T < 12,5 (square and rectangular) the minimum elongation is reduced by 2.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-1).

with dimensional and/or mass tolerances in accordance with:-

- BS EN 10210-2
- BS EN 10219-2

A.1.4 Acceptable British/European structural steel: sheet piles

BS EN 10248-1: 1996 - Hot finished non-alloy steels

Grade	Thickness (mm)	Chemical composition (%) [a]			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
S240GP	t ≤ 8.5 8.5 < t ≤ 25	0.200	0.045	0.045	^	240	340	26	-
S270GP	t ≤ 8.5 8.5 < t ≤ 25	0.240	0.045	0.045	^	270	410	24	-
S320GP	t ≤ 8.5 8.5 < t ≤ 25	0.240	0.045	0.045	^	320	440	23	-
S355GP	t ≤ 8.5 8.5 < t ≤ 25	0.240	0.045	0.045	^	355	480	22	-
S390GP	t ≤ 8.5 8.5 < t ≤ 25	0.240	0.040	0.040	^	390	490	20	-
S430GP	t ≤ 8.5 8.5 < t ≤ 25	0.240	0.040	0.040	^	430	510	19	-

Note: a. Ladle analysis.
^ To be specified by the purchaser.

BS EN 10249-1: 1996 – Cold formed sheet piling of non-alloy steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
S235JRC	t ≤ 25	*Refer to BS EN 10025-2 in Section A.1.1*							
S275JRC	t ≤ 25								
S335J0C	t ≤ 25								

with dimensional and/or mass tolerances in accordance with:-

- BS EN 10248-2
- BS EN 10249-2
- BS EN 10051

A.1.5 Acceptable British/European structural steel: solid bars

BS EN 10025-2: 2019 - Non-alloy Structural Steel

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P [b]	S [b]					
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S235JR	150 < t ≤ 200	0.20	0.035	0.035	0.40	185	340 ~ 490	21	≥ 27J @ 20°C
	200 < t ≤ 250					175			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S235J0	150 < t ≤ 200	0.17	0.030	0.030	0.40	185	340 ~ 490	21	≥ 27J @ 0°C
	200 < t ≤ 250					175			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S235J2	150 < t ≤ 200	0.17	0.025	0.025	0.40	185	340 ~ 490	21	≥ 27J @ -20°C
	200 < t ≤ 250					175			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S275JR	150 < t ≤ 200	0.22	0.035	0.035	0.44	215	380 ~ 540	18	≥ 27J @ 20°C
	200 < t ≤ 250					205			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S275J0	150 < t ≤ 200	0.20	0.030	0.030	0.44	215	380 ~ 540	18	≥ 27J @ 0°C
	200 < t ≤ 250					205			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S275J2	150 < t ≤ 200	0.20	0.025	0.025	0.44	215	380 ~ 540	18	≥ 27J @ -20°C
	200 < t ≤ 250					205			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S355JR	150 < t ≤ 200	0.24	0.035	0.035	0.54	285	450 ~ 600	17	≥ 27J @ 20°C
	200 < t ≤ 250					275			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S355J0	150 < t ≤ 200	0.22	0.030	0.030	0.54	285	450 ~ 600	17	≥ 27J @ 0°C
	200 < t ≤ 250					275			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S355J2	150 < t ≤ 200	0.22	0.025	0.025	0.54	285	450 ~ 600	17	≥ 27J @ -20°C
	200 < t ≤ 250					275			
	3 ≤ t ≤ 150	*Refer to BS EN 10025-2 in Section A.1.1*							
S355K2	150 < t ≤ 200	0.22	0.025	0.025	0.54	285	450 ~ 600	17	≥ 40J @ -20°C
	200 < t ≤ 250					275			
	3 ≤ t ≤ 63	*Refer to BS EN 10025-2 in Section A.1.2*							
S460JR	63 < t ≤ 80					400	550 ~ 720		
	80 < t ≤ 100	0.22	0.030	0.030	0.49	390		17	≥ 27J @ 20°C
	100 < t ≤ 150					390	530 ~ 700		
	3 ≤ t ≤ 63	*Refer to BS EN 10025-2 in Section A.1.2*							
S460J0[j]	63 < t ≤ 80					400	550 ~ 720		
	80 < t ≤ 100	0.22	0.030	0.030	0.49	390		17	≥ 27J @ 0°C
	100 < t ≤ 150					390	530 ~ 700		

(To be continued)

(Continued)

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [a] (%)	Impact toughness (J)
		C	P [b]	S [b]					
S460J2[j]	3 ≤ t ≤ 63	*Refer to BS EN 10025-2 in Section A.1.2*							
	63 < t ≤ 80	0.22	0.030	0.030	0.49	400	550 ~ 720	17	≥ 27J @ -20°C
	80 < t ≤ 100					390			
	100 < t ≤ 150					390	530 ~ 700		
S460K2	3 ≤ t ≤ 63	*Refer to BS EN 10025-2 in Section A.1.2*							
	63 < t ≤ 80	0.22	0.030	0.030	0.49	400	550 ~ 720	17	≥ 40J @ 20°C
	80 < t ≤ 100					390			
	100 < t ≤ 150					390	530 ~ 700		
S500J0	3 ≤ t ≤ 63	*Refer to BS EN 10025-2 in Section A.1.2*							
	63 < t ≤ 80	0.22	0.030	0.030	0.49	450	580 ~ 760	15	≥ 27-J @ 0°C
	80 < t ≤ 100					450			
	100 < t ≤ 150					450	560 ~ 750		

Note: a. The direction parallel to the rolling direction applies.
b. For long products the P and S content can be 0.005% higher.

BS EN 10025-3: 2019 - Normalized Rolled Weldable Fine Grain Structural Steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness [b] (J)
		C	P [e]	S [e]					
S275N	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.180	0.030	0.025	0.42	215	350 ~ 480	23	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	200 < t ≤ 250					205	350 ~ 480		
S275NL	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.160	0.025	0.020	0.42	215	350 ~ 480	23	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	200 < t ≤ 250					205	350 ~ 480		
S355N	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.200	0.030	0.025	0.45	285	450 ~ 600	21	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	200 < t ≤ 250					275	450 ~ 600		
S355NL	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.180	0.025	0.020	0.45	285	450 ~ 600	21	≥ 63J @ 20°C ≥ 55J @ 0°C ≥ 51J @ -10°C ≥ 47J @ -20°C ≥ 40J @ -30°C ≥ 31J @ -40°C ≥ 27J @ -50°C
	200 < t ≤ 250					275	450 ~ 600		
S420N	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.200	0.030	0.025	0.52	330	500 ~ 650	18	≥ 55J @ 20°C ≥ 47J @ 0°C ≥ 43J @ -10°C ≥ 40J @ -20°C [c]
	200 < t ≤ 250					320	500 ~ 650		

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness [b] (J)
		C	P [e]	S [e]					
S420NL	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.200	0.025	0.020	0.52	330	500 ~ 650	18	≥ 63J @ 20ºC ≥ 55J @ 0ºC ≥ 51J @ -10ºC ≥ 47J @ -20ºC ≥ 40J @ -30ºC ≥ 31J @ -40ºC ≥ 27J @ -50ºC
	200 < t ≤ 250					320	500 ~ 650		
S460N	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.200	0.030	0.025	0.55	370	530 ~ 710	17	≥ 55J @ 20ºC ≥ 47J @ 0ºC ≥ 43J @ -10ºC ≥ 40J @ -20ºC [c]
	200 < t ≤ 250					370	510 ~ 690	16	
S460NL	t ≤ 150	*Refer to BS EN 10025-3 in Section A.1.1*							
	150 < t ≤ 200	0.200	0.025	0.020	0.55	370	530 ~ 710	17	≥ 63J @ 20ºC ≥ 55J @ 0ºC ≥ 51J @ -10ºC ≥ 47J @ -20ºC ≥ 40J @ -30ºC ≥ 31J @ -40ºC ≥ 27J @ -50ºC
	200 < t ≤ 250					370	510 ~ 690	16	

Note: a. The direction parallel to the rolling direction applies.
b. Minimum values of impact energy KV2 on longitudinal test pieces.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-10).
e. For long products the P and S content can be 0.005% higher.

BS EN 10025-4: 2019 - Thermo-mechanical Rolled Weldable Fine Grain Structural Steels

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P [e]	S [e]					
S275M	t ≤ 150	0.15	*Refer to BS EN 10025-4 in Section A.1.1*						
S275ML	t ≤ 150	0.15							
S355M	t ≤ 150	0.16							
S355ML	t ≤ 150	0.16							
S420M	t ≤ 150	0.18							
S420ML	t ≤ 150	0.18							
S460M	t ≤ 150	0.18							
S460ML	t ≤ 150	0.18							
S500M	t ≤ 150	0.18							
S500ML	t ≤ 150	0.18							

Note: e. For long products the P and S content can be 0.005% higher.

BS EN 10025-5: 2019 - Structural Steels with Improved Atmospheric Corrosion Resistance

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P [e]	S [e]					
S355J0WP	3 ≤ t ≤ 40	*Refer to BS EN 10025-5 in Section A.1.1*							
S355J2WP	3 ≤ t ≤ 40								
S355J5W	3 ≤ t ≤ 63	*Refer to BS EN 10025-5 in Section A.1.2*							
	63 < t ≤ 80					325	470 ~ 630	20	
	80 < t ≤ 100	0.16	max. 0.030	0.025	0.52	315			≥ 27J @ -50ºC
	100 < t ≤ 150					295	450 ~ 600	18	
S420J0W	3 ≤ t ≤ 16					420		19	
	16 < t ≤ 40					400			
	40 < t ≤ 63	0.20	max. 0.035	0.035	0.52	390	500 ~ 660	18	≥ 27J @ 0ºC
	63 < t ≤ 80					380		17	
	80 < t ≤ 100					370			
	100 < t ≤ 150					365	460 ~ 620	16	
S420J2W	3 ≤ t ≤ 16					420		19	
	16 < t ≤ 40					400			
	40 < t ≤ 63	0.20	max. 0.030	0.030	0.52	390	500 ~ 660	18	≥ 27J @ -20ºC
	63 < t ≤ 80					380		17	
	80 < t ≤ 100					370			
	100 < t ≤ 150					365	460 ~ 620	16	
S420K2W	3 ≤ t ≤ 16					420		19	
	16 < t ≤ 40					400			
	40 < t ≤ 63	0.20	max. 0.030	0.030	0.52	390	500 ~ 660	18	≥ 40J @ -20ºC
	63 < t ≤ 80					380		17	
	80 < t ≤ 100					370			
	100 < t ≤ 150					365	460 ~ 620	16	
S420J4W	3 ≤ t ≤ 63	*Refer to BS EN 10025-5 in Section A.1.2*							
	63 < t ≤ 80					380	500 ~ 660	17	
	80 < t ≤ 100	0.20	max. 0.030	0.025	0.52	370			≥ 27J @ -40ºC
	100 < t ≤ 150					365	460 ~ 620	16	
S420J5W	3 ≤ t ≤ 63	*Refer to BS EN 10025-5 in Section A.1.2*							
	63 < t ≤ 80					380	500 ~ 660	17	
	80 < t ≤ 100	0.20	max. 0.030	0.025	0.52	370			≥ 27J @ -50ºC
	100 < t ≤ 150					365	460 ~ 620	16	
S460J0W	3 ≤ t ≤ 16					460		17	
	16 < t ≤ 40					440			
	40 < t ≤ 63	0.20	max. 0.035	0.035	0.52	430	530 ~ 710	16	≥ 27J @ 0ºC
	63 < t ≤ 80					410		15	
	80 < t ≤ 100					400			
	100 < t ≤ 150					385	490 ~ 660	14	

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P [e]	S [e]					
S460J2W	3 ≤ t ≤ 16	0.20	max. 0.030	0.030	0.52	460	530 ~ 710	17	≥ 27J @ -20°C
	16 < t ≤ 40					440			
	40 < t ≤ 63					430		16	
	63 < t ≤ 80					410		15	
	80 < t ≤ 100					400			
	100 < t ≤ 150					385	490 ~ 660	14	
S460K2W	3 ≤ t ≤ 16	0.20	max. 0.030	0.030	0.52	460	530 ~ 710	17	≥ 40J @ -20°C
	16 < t ≤ 40					440			
	40 < t ≤ 63					430		16	
	63 < t ≤ 80					410		15	
	80 < t ≤ 100					400			
	100 < t ≤ 150					385	490 ~ 660	14	
S460J4W	3 ≤ t ≤ 63	*Refer to BS EN 10025-5 in Section A.1.2*							
	63 < t ≤ 80	0.20	max. 0.030	0.025	0.52	410	530 ~ 710	15	≥ 27J @ -40°C
	80 < t ≤ 100					400			
	100 < t ≤ 150					385	490 ~ 660	14	
S460J5W	3 ≤ t ≤ 63	*Refer to BS EN 10025-5 in Section A.1.2*							
	63 < t ≤ 80	0.20	max. 0.030	0.025	0.52	410	530 ~ 710	15	≥ 27J @ -50°C
	80 < t ≤ 100					400			
	100 < t ≤ 150					385	490 ~ 660	14	

Note: a. Longitudinal values.
b. Minimum values of impact energy KV2 on longitudinal test pieces.
e. For long products the P and S content can be 0.005% higher.

BS EN 10025-6: 2019 – High Strength Structural Steels in the Quenched and Tempered Condition

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness [b] (J)
		C	P	S					
S460Q	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.025	0.015	0.50	400	500 ~ 670	17	≥ 40J @ 0°C ≥ 30J @ -20°C
S460QL	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.50	400	500 ~ 670	17	≥ 50J @ 0°C ≥ 40J @ -20°C ≥ 30J @ -40°C
S460QL1	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.50	400	500 ~ 670	17	≥ 60J @ 0°C ≥ 50J @ -20°C ≥ 40J @ -40°C ≥ 30J @ -60°C
S500Q	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.025	0.015	0.70	440	540 ~ 720	17	≥ 40J @ 0°C ≥ 30J @ -20°C

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness [b] (J)
		C	P	S					
S500QL	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.70	440	540 ~ 720	17	≥ 50J @ 0ºC ≥ 40J @ -20ºC ≥ 30J @ -40ºC
S500QL1	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.70	440	540 ~ 720	17	≥ 60J @ 0ºC ≥ 50J @ -20ºC ≥ 40J @ -40ºC ≥ 30J @ -60ºC
S550Q	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.025	0.015	0.83	490	590 ~ 770	16	≥ 40J @ 0ºC ≥ 30J @ -20ºC
S550QL	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.83	490	590 ~ 770	16	≥ 50J @ 0ºC ≥ 40J @ -20ºC ≥ 30J @ -40ºC
S550QL1	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.83	490	590 ~ 770	16	≥ 60J @ 0ºC ≥ 50J @ -20ºC ≥ 40 @ -40ºC ≥ 30J @ -60ºC
S620Q	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.025	0.015	0.83	560	650 ~ 830	15	≥ 40J @ 0ºC ≥ 30J @ -20ºC
S620QL	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.83	560	650 ~ 830	15	≥ 50J @ 0ºC ≥ 40J @ -20ºC ≥ 30J @ -40ºC
S620QL1	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.83	560	650 ~ 830	15	≥ 60J @ 0ºC ≥ 50J @ -20ºC ≥ 40J @ -40ºC ≥ 30J @ -60ºC
S690Q	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.025	0.015	0.83	630	710 ~ 900	14	≥ 40J @ 0ºC ≥ 30J @ -20ºC
S690QL	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.83	630	710 ~ 900	14	≥ 50J @ 0ºC ≥ 40J @ -20ºC ≥ 30J @ -40ºC
S690QL1	3 ≤ t ≤ 150	*Refer to BS EN 10025-6 in Section A.1.1*							
	100 < t ≤ 200	0.20	0.020	0.010	0.83	630	710 ~ 900	14	≥ 60J @ 0ºC ≥ 50J @ -20ºC ≥ 40J @ -40ºC ≥ 30J @ -60ºC

Note: b. Minimum values of impact energy KV2 on longitudinal test pieces.

with dimensional and/or mass tolerances in accordance with:

- BS EN 10058
- BS EN 10059
- BS EN 10060

A.1.6 Acceptable British/European structural steel: strips for cold formed open sections

BS EN 10025-2: 2019 - Non-alloy Structural Steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness [b] (J)
		C	P	S					
S235JR	0.6 ≤ t < 3	0.17	0.035	0.035	0.35	235	360 ~ 510	26	≥ 27J @ 20ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S235J0	0.6 ≤ t < 3	0.17	0.030	0.030	0.35	235	360 ~ 510	26	≥ 27J @ 0ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S235J2	0.6 ≤ t < 3	0.17	0.025	0.025	0.35	235	360 ~ 510	26	≥ 27J @ -20ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S275JR	0.6 ≤ t < 3	0.21	0.035	0.035	0.40	275	410 ~ 580	23	≥ 27J @ 20ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S275J0	0.6 ≤ t < 3	0.18	0.030	0.030	0.40	275	410 ~ 580	23	≥ 27J @ 0ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S275J2	0.6 ≤ t < 3	0.18	0.025	0.025	0.40	275	410 ~ 580	23	≥ 27J @ -20ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S355JR	0.6 ≤ t < 3	0.24	0.035	0.035	0.45	355	510 ~ 680	22	≥ 27J @ 20ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S355J0	0.6 ≤ t < 3	0.20	0.030	0.030	0.45	355	510 ~ 680	22	≥ 27J @ 0ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S355J2	0.6 ≤ t < 3	0.20	0.025	0.025	0.45	355	510 ~ 680	22	≥ 27J @ -20ºC
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							
S355K2	0.6 ≤ t < 3	0.20	0.025	0.025	0.45	355	510 ~ 680	22	≥ 40J @ -20ºC [c]
	3 ≤ t ≤ 8	*Refer to BS EN 10025-2 in Section A.1.1*							

Note: a. The direction parallel to the rolling direction applies.
b. Minimum values of impact energy KV2 on longitudinal test pieces.
c. This value corresponds with 27 J at - 30 °C (see EN 1993-1-10).

BS EN 10149-2: 2013 - Thermomechanically rolled steels

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
S315MC	1.5 ≤ t < 3	0.12	0.025	0.020	-	315	390 ~ 510	20	-
	3 ≤ t ≤ 20							24	
S355MC	1.5 ≤ t < 3	0.12	0.025	0.020	-	355	430 ~ 550	19	-
	3 ≤ t ≤ 20							23	
S420MC	1.5 ≤ t < 3	0.12	0.025	0.015	-	420	480 ~ 620	16	-
	3 ≤ t ≤ 20							19	
S460MC	1.5 ≤ t < 3	0.12	0.025	0.015	-	460	520 ~ 670	14	-
	3 ≤ t ≤ 20							17	
S500MC	1.5 ≤ t < 3	0.12	0.025	0.015	-	500	550 ~ 700	12	-
	3 ≤ t ≤ 16							14	
S550MC	1.5 ≤ t < 3	0.12	0.025	0.015	-	550	600 ~ 760	12	-
	3 ≤ t ≤ 16							14	
S600MC	1.5 ≤ t < 3	0.12	0.025	0.015	-	600	650 - 820	11	-
	3 ≤ t ≤ 16							13	

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness (J)
		C	P	S					
S650MC	1.5 ≤ t < 3	0.12	0.025	0.015	-	650 [d]	700 - 880	10	-
	3 ≤ t ≤ 16							12	
S700MC	1.5 ≤ t < 3	0.12	0.025	0.015	-	700 [d]	750 – 950	10	-
	3 ≤ t ≤ 16							12	

Note: a. The values for the tensile test apply to longitudinal test pieces. For thicknesses < 3 mm, L_o = 80 mm, otherwise $L_o = 5.65 \sqrt{S_o}$.
d. For thicknesses > 8 mm the minimum yield strength can be 20 MPa lower.

BS EN 10149-3: 2013 - Normalized or normalized rolled steels

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness (J)
		C	P	S					
S260NC	1.5 ≤ t < 3	0.16	0.025	0.020	-	260	370 ~ 490	24	-
	3 ≤ t ≤ 20							30	
S315NC	1.5 ≤ t < 3	0.16	0.025	0.020	-	315	430 ~ 550	22	-
	3 ≤ t ≤ 20							27	
S355NC	1.5 ≤ t < 3	0.18	0.025	0.015	-	355	470 ~ 610	20	-
	3 ≤ t ≤ 20							25	
S420NC	1.5 ≤ t < 3	0.20	0.025	0.015	-	420	530 ~ 670	18	-
	3 ≤ t ≤ 20							23	

Note: a. The values for the tensile test apply to longitudinal test pieces. For thicknesses < 3 mm, L_o = 80 mm, otherwise $L_o = 5.65 \sqrt{S_o}$.

BS EN 10346: 2015 - Continuously hot-dip coated steel flat products

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s [a] (N/mm²)	U_s [b] (N/mm²)	ε_L [c] (%)	Impact toughness (J)
		C	P	S					
S220GD	0.6 ≤ t ≤ 3.0	0.20	0.10	0.045	-	220	> 300	20	-
S250GD	0.6 ≤ t ≤ 3.0					250	> 330	19	-
S280GD	0.6 ≤ t ≤ 3.0					280	> 360	18	-
S320GD	0.6 ≤ t ≤ 3.0					320	> 390	17	-
S350GD	0.6 ≤ t ≤ 3.0					350	> 420	16	-
S390GD	0.6 ≤ t ≤ 3.0					390	> 460	16	-
S420GD	0.6 ≤ t ≤ 3.0					420	> 480	15	-
S450GD	0.6 ≤ t ≤ 3.0					450	> 510	14	-
S550GD	0.6 ≤ t ≤ 3.0					550	> 560	-	-

Note: a. Proof strength $R_{p0.2}$. If the yield point is pronounced, the values apply to the upper yield point R_{eH}.
b. For all grades except S550GD, a range of 140 MPa can be expected for tensile strength.
c. Decreased minimum elongation values apply for product thickness:
0.50mm < t < 0.70mm (minus 2 units).

with dimensional and/or mass tolerances in accordance with:-

- BS EN 10051
- BS EN 10143

A.1.7 Acceptable British/European strips for cold-formed steel profiled sheetings

BS EN 10346: 2015 - Continuously hot-dip coated steel flat products

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s [a] (N/mm²)	U_s [b] (N/mm²)	ε_L [c] (%)	Impact toughness (J)
		C	P	S					
S220GD	0.35 ≤ t ≤ 1.5	0.20	0.10	0.045	-	220	> 300	20	-
S250GD	0.35 ≤ t ≤ 1.5					250	> 330	19	-
S280GD	0.35 ≤ t ≤ 1.5					280	> 360	18	-
S320GD	0.35 ≤ t ≤ 1.5					320	> 390	17	-
S350GD	0.35 ≤ t ≤ 1.5					350	> 420	16	-
S390GD	0.35 ≤ t ≤ 1.5					390	> 460	16	-
S420GD	0.35 ≤ t ≤ 1.5					420	> 480	15	-
S450GD	0.35 ≤ t ≤ 1.5					450	> 510	14	-
S550GD	0.35 ≤ t ≤ 1.5					550	> 560	-	-
S550GD	0.35 ≤ t ≤ 1.5					550	> 560	-	-

Note: a. Proof strength $R_{p0.2}$. If the yield point is pronounced, the values apply to the upper yield point R_{eH}.
b. For all grades except S550GD, a range of 140 MPa can be expected for tensile strength.
c. Decreased minimum elongation values apply for product thickness:
0.50mm < t < 0.70mm (minus 2 units);
0.35mm < t < 0.50mm (minus 4 units).

with dimensional and/or mass tolerances in accordance with:-

- BS EN 10143

A.1.8 Acceptable British/European stud connectors

Stud shear connectors manufactured to:-

- BS EN ISO 13918
- BS EN ISO 898-1

A.1.9 Acceptable British/European non-preloaded bolting assemblies

Bolts manufactured to:-

- BS 4190
- BS 7419
- BS EN ISO 4014
- BS EN ISO 4016
- BS EN ISO 4017
- BS EN ISO 4018

Nuts manufactured to:-

- BS 4190
- BS EN ISO 4032
- BS EN ISO 4033
- BS EN ISO 4034

Washers manufactured to:-

- BS EN ISO 898-3
- BS EN ISO 7091
- BS EN ISO 7092
- BS EN ISO 7093-1
- BS EN ISO 7093-2
- BS EN ISO 7094

A.1.10 Acceptable British/European preloaded bolting assemblies

Bolts, Nuts and Washers manufactured to:-

- BS EN 14399-1
- BS EN 14399-2
- BS EN 14399-3
- BS EN 14399-4
- BS EN 14399-5
- BS EN 14399-6
- BS EN 14399-7
- BS EN 14399-8
- BS EN 14399-9
- BS EN 14399-10

A.1.11 Acceptable British/European welding consumables

Welding consumables, which result in all-weld metals meeting material performance requirements in **3.3.1.11**, and manufactured to:-

- BS EN ISO 14174
- BS EN ISO 636
- BS EN ISO 2560
- BS EN ISO 14171
- BS EN ISO 14341
- BS EN ISO 14343
- BS EN ISO 16834
- BS EN ISO 17632
- BS EN ISO 17633
- BS EN ISO 17634
- BS EN ISO 18274
- BS EN ISO 21952
- BS EN ISO 24373
- BS EN ISO 24598
- BS EN ISO 26304

A.2 Acceptable American steel materials

A.2.1 Acceptable American structural steel: plates

ASTM A36 – 2019: Carbon Structural Steel

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness (J)
		C	P	S					
Grade 36 [250]	3 ≤t ≤ 20	0.250	0.030	0.030	^	250	400 ~ 550	20	≥ 27J @ 21°C**
	20 < t ≤ 40	0.250							
	40 < t ≤ 65	0.260							
	65 < t ≤ 100	0.270*							
	100 < t ≤ 150	0.290*							

Note: [a] The length of test pieces is 200mm.
^ To be specified by the purchaser.
* Material test should be conducted to verify the Phosphorus content to be smaller than 0.045%.
** This requirement shall be applied unless specified in the order.

ASTM A242–2013(R2018): High-Strength Low-Alloy Structural Steel

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness (J)
		C	P	S					
Grade 50 [345]	3≤ t ≤ 20	0.150	0.15	0.050	^	345	480	18	≥ 27J @ 21°C**
	20 < t ≤ 40					315	460		
	40 < t ≤ 100					290	435		

Note: [a] The length of test pieces is 200mm.
^ To be specified by the purchaser.
** This requirement shall be applied unless specified in the order.

ASTM A572–2021: High-Strength Low-Alloy Columbium-Vanadium Structural Steel

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [a] (%)	Impact toughness (J)
		C	P	S					
Grade 42 [290]	3 ≤ t ≤ 150	0.210	0.030	0.030	^	290	415	20	≥ 27J @ 21°C**
Grade 50 [345]	3 ≤ t ≤ 100	0.230				345	450	18	
Grade 55 [380]	3 ≤ t ≤ 64	0.250				380	485	17	
Grade 60 [415]	3 ≤ t ≤ 64	0.260				415	520	16	
Grade 65 [450]	3 ≤ t ≤ 25	0.230				450	550	15	
	25 ≤ t ≤ 50	0.260							

Note: [a] The length of test pieces is 200mm.
^ To be specified by the purchaser.
** This requirement shall be applied unless specified in the order.

ASTM A588–2019: High-Strength Low-Alloy Steel with Atmospheric Corrosion Resistance

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L[a] (%)	Impact toughness (J)
		C	P	S					
Grade 50 [345]	3 ≤ t ≤ 100	0.190	0.030	0.030	^	345	485	18	≥ 27J @ 21°C**
	100 < t ≤ 125					315	460		
	125 < t ≤ 150					290	435		

Note: [a] The length of test pieces is 200mm.
^ To be specified by the purchaser.
** This requirement shall be applied unless specified in the order.

ASTM A709–2021: Structural Steel for Bridges

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade 36 [250]	3 ≤ t ≤ 20	0.260 [c]	0.040 [c]	0.050 [c]	^	250	400 ~ 550	20 [a]	T*: 20J @ 21°C T*: 20J @ 4°C T*: 20J @-12°C F**: 34J @ 21°C F**: 34J @ 4°C F**: 34J @-12°C
	20 < t ≤ 40	0.270 [c]							
	40 < t ≤ 75	0.280 [c]							
	75 < t ≤ 100	0.280 [c]					400		
Grade 50 [345]	3 ≤ t ≤ 50	0.230	0.030	0.030	^	345	450	18 [a]	T*: 20J @ 21°C T*: 20J @ 4°C T*: 20J @-12°C F**: 34J @ 21°C F**: 34J @ 4°C F**: 34J @-12°C
	50 < t ≤ 100								T*: 27J @ 21°C T*: 27J @ 4°C T*: 27J @-12°C F**: 41J @ 21°C F**: 41J @ 4°C F**: 41J @-12°C
Grade 50W [345W]	3 ≤ t ≤ 50	0.19 (A) 0.20 (B)	0.030	0.030	^	345	485	18 [a]	T*: 20J @ 21°C T*: 20J @ 4°C T*: 20J @-12°C F**: 34J @ 21°C F**: 34J @ 4°C F**: 34J @-12°C
	50 < t ≤ 100								T*: 27J @ 21°C T*: 27J @ 4°C T*: 27J @-12°C F**: 41J @ 21°C F**: 41J @ 4°C F**: 41J @-12°C
Grade HPS 50W [HPS 345W]	3 ≤ t ≤ 100	0.110	0.020	0.006	^	345	485	18 [a]	T*: 27J @-12°C F**: 41J @-12°C

(To be continued)

(Continued)

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade 50CR [345C]	3 ≤ t ≤ 50	0.03	0.040	0.010	^	345	485	18 [a]	T*: 20J @ 21°C T*: 20J @ 4°C T*: 20J @-12°C F**: 34J @ 21°C F**: 34J @ 4°C F**: 34J @-12°C
Grade HPS 70W [HPS 485W]	3 ≤ t ≤ 100	0.110	0.020	0.006	^	485	585 ~ 760	19 [b]	T*: 34J @-23°C F**: 48J @-23°C
Grade HPS 100W [HPS 690W]	3 ≤ t ≤ 65	0.080	0.015	0.006	^	690	760 ~ 895	18 [b]	T*: 34J @-23°C T*: 48J @-34°C F**: 48J @-23°C
	65 < t ≤ 100					620	690 ~ 895	16 [b]	

Note: [a] The length of test pieces is 200mm.
[b] The length of test pieces is 50mm.
[c] Only for plate with width ≤ 380 mm.
^ To be specified by the purchaser.
* T is designated as Non-fracture-critical tension components.
** F is designated as Fracture-critical tension components.

ASTM A945–2016(R2021): High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L[a] (%)	Impact toughness (J)
		C	P	S					
Grade 50 [345]	3 ≤ t ≤ 50	0.100	0.025	0.010	^	345	485 ~ 620	21	>27J @-40°C
Grade 65 [450]	3 ≤ t ≤ 65					450	540 ~ 690	18	>95J @-40°C

Note: [a] The length of test pieces is 200mm.
^ To be specified by the purchaser.

ASTM A1066–2022: High-Strength Low-Alloy Structural Steel Plate Produced by Thermo-Mechanical Controlled Process (TMCP)

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L[a] (%)	Impact toughness (J)
		C	P	S					
Grade 50 [345]	3 ≤ t ≤ 150	0.140	0.030	0.020	0.40	345	450	18	> 48J @-23°C
Grade 60 [415]	3 ≤ t ≤ 150	0.160			0.43	415	520	16	
Grade 65 [450]	3 ≤ t ≤ 150				0.45	450	550	15	
Grade 70 [485]	3 ≤ t ≤ 75				0.47	485	585	14	
Grade 80 [550]	3 ≤ t ≤ 25				0.50	550	620	13	

Note: [a] The length of test pieces is 200mm.

with dimensional and/or mass tolerances in accordance with:-

ASTM A6-2021: Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

Specified thickness (mm)	Permitted Variations Over Specified Thickness for Widths (m)						
	w ≤ 1.2	1.2 < w < 1.5	1.5 ≤w < 1.8	1.8 ≤ w < 2.1	2.1 ≤ w <2.4	2.4 ≤ w < 2.7	2.7 ≤w < 3.0
5 ≤ t ≤ 20	0.8	0.8	0.8	0.8	0.8~0.9	0.8~1.0	0.8~1.2
22 ≤ t ≤ 40	0.8~1.5	0.9~1.5	0.9~1.6	0.9~1.6	1.0~1.6	1.1~1.8	1.3~2.0
45 ≤ t ≤ 60	1.6~2.3	1.6~2.3	1.7~2.3	1.8~2.4	1.8~2.4	2.0~2.8	2.3~3.0
73 ≤ t ≤ 100	2.5~3.3	2.5~3.3	2.5~3.3	2.6~3.3	2.6~3.5	3.0~3.8	3.3~3.8
110- ≤ t ≤ 140	3.5~4.3	3.5~4.3	3.5~4.3	3.5~4.3	3.5~4.3	3.8~4.3	3.8~4.3
153 ≤ t ≤ 180	4.5~5.4	4.5~5.4	4.5~5.4	4.5~5.4	4.5~5.4	4.5~5.4	4.5~5.4
203 ≤ t ≤ 300	5.8~7.5	5.8~7.5	6.0~9.0	6.0~9.0	6.0~9.0	6.0~9.0	6.0~9.0

A.2.2 Acceptable American structural steel: sections

ASTM A36 – 2019: Carbon Structural Steel

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade 36 [250]	3 ≤ t ≤ 80	*Refer to ASTM A36 in Section A.2.1*							

ASTM A572–2021: High-Strength Low-Alloy Columbium-Vanadium Structural Steel

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade 42 [290]	3 ≤ t ≤ 80	*Refer to ASTM A572 in Section A.2.1*							
Grade 50 [345]	3 ≤ t ≤ 80								
Grade 55 [380]	3 ≤ t ≤ 64								
Grade 60 [415]	3 ≤ t ≤ 64								
Grade 65 [450]	3 ≤ t ≤ 25								
	25 ≤ t ≤ 50								

ASTM A588–2019: High-Strength Low-Alloy Steel with Atmospheric Corrosion Resistance

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade 50 [345]	3 ≤ t ≤ 80	*Refer to ASTM A588 in Section A.2.1*							

ASTM A913/913M–2019: High-Strength Low-Alloy Steel Shapes Produced by Quenching and Self-Tempering Process (QST)

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L[a] (%)	Impact toughness (J)
		C	P	S					
Grade 50 [345]	3 ≤ t ≤ 50	0.120	0.030	0.030	0.38	345	450	18	>54J @21ºC
Grade 60 [415]	3 ≤ t ≤ 80				0.40	415	520	16	
Grade 65 [450]	3 ≤ t ≤ 80				0.43	450	550	15	
Grade 70 [485]	3 ≤ t ≤ 80				0.45	485	620	14	
Grade 80 [550]	3 ≤ t ≤ 80	0.160			0.49	550	655	13	

Note: [a] The length of test pieces is 200mm.

ASTM A709–2021: Structural Steel for Bridges

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness * (J)
		C	P	S					
36 [250]	3 ≤ t ≤ 75	*Refer to ASTM A709 in Section A.2.1*						20 [a]	*Refer to ASTM A709 in Section A.2.1*
50 [345]	3 ≤ t ≤ 80	*Refer to ASTM A709 in Section A.2.1*						18 [a]	*Refer to ASTM A709 in Section A.2.1*
QST 50 [QST 345]	3 ≤ t ≤ 50	0.12	0.030	0.030	0.38	345	450	18 [a]	T*: 20J @ 21°C, 4°C, -12°C F**: 34J @ 21°C, 4°C, -12°C
	50 < t ≤ 80								T*: 27J @ 21°C, 4°C, -12°C F**: 41J @ 21°C, 4°C, -12°C
50S [345S]	3 ≤ t ≤ 50	0.230	0.035	0.045	^	345~450	450	18 [a]	T*: 20J @ 21°C, 4°C, -12°C F**: 34J @ 21°C, 4°C, -12°C
	50 < t ≤ 80								T*: 27J @ 21°C, 4°C, -12°C F**: 41J @ 21°C, 4°C, -12°C
QST 50S [QST 345S]	3 ≤ t ≤ 80	0.12	0.030	0.030	0.47 [b]	345~450	450	18 [a]	T*: 20J @ 21°C, 4°C, -12°C F**: 34J @ 21°C, 4°C, -12°C
50W [345W]	3 ≤ t ≤ 10	0.19	0.030	0.030	^	345	485	18 [a]	T*: 20J @ 21°C, 4°C, -12°C F**: 34J @ 21°C, 4°C, -12°C
HPS 50W [HPS 345W]	3 ≤ t ≤ 80	0.11	0.020	0.006	^	345	485	18 [a]	T*: 27J @ -12°C F**: 41J @ -12°C
QST 65 [QST 450]	3 ≤ t ≤ 50	0.12	0.030	0.030	0.43	450	550	15 [a]	T*: 27J @ 21°C, 4°C, -12°C F**: 41J @ 21°C, 4°C, -12°C
	50 < t ≤ 80								T*: 34J @ 21°C, 4°C, -12°C F**: 48J @ 21°C, 4°C, -12°C
QST 70 [QST 485]	3 ≤ t ≤ 50	0.12	0.030	0.030	0.45	485	620	14 [a]	T*: 27J @ 21°C, 4°C, -12°C F**: 41J @ 21°C, 4°C, -12°C
	50 < t ≤ 80								T*: 34J @ 21°C, 4°C, -12°C F**: 48J @ 21°C, 4°C, -12°C

Note: [a] The length of test pieces is 200mm.
[b] The value is only for shapes with flange thickness over 50 mm, and 0.45 % in other shapes.
^ To be specified by the purchaser.
* T is designated as Non-fracture-critical tension components.
** F is designated as Fracture-critical tension components.

ASTM A992/A992M–2020: Structural Steel Shapes

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L[a] (%)	Impact toughness (J)
		C	P	S					
Grade 50 [345]	3 ≤ t ≤ 80	0.230	0.035	0.045	0.47 [b]	345	450	18	⩾ 27J @ 21°C**
Grade 60 [415]						415			
Grade 65 [450]						450			

Note: [a] The length of test pieces is 200mm.
[b] The value is only for shapes with flange thickness over 50 mm, and 0.45 % in other shapes.
** This requirement shall be applied unless specified in the order.

with dimensional and/or mass tolerances in accordance with: -

ASTM A6-2021: Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

Product shape	Section normal size, mm	Permitted Variations in thickness (mm)			
		A Depth		B Flange Width	
		over	under	over	under
W and HP	≤310	4	3	6	5
	>310	4	3	6	5
S and M	75~180	2	2	3	3
	180~360	3	2	4	4
	360~610	5	3	5	5
C and MC	≤40	1	1	1	1
	40~75	2	2	2	2
	75~180	3	2	3	3
	180~360	3	3	3	4
	>360	5	4	3	5

A.2.3 Acceptable American structural steel: hollow sections

ASTM A501–2021: Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade A [250]	3 ≤ t ≤ 25	0.260	0.035	0.035	^	270	400	25	>27J @-19ºC
	25 < t ≤ 50					260			
	50 < t ≤ 76					250			
	76 < t ≤ 100					240			
Grade B [345]	3 ≤ t ≤ 25	0.220	0.030	0.020	^	315	448	24	
	25 < t ≤ 50					310			
	50 < t ≤ 76					290			
	76 < t ≤ 100					280			
Grade C	3 ≤ t ≤ 25	0.220	0.030	0.020	^	345	483	23	
	25 < t ≤ 50					340			
	50 < t ≤ 76					330			
	76 < t ≤ 100					315			

^ To be specified by the purchaser.

API 5L–2018: Specification for Line Pipe

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade B [L245]	4.5 ≤ t ≤ 80	0.28(S*) 0.26(W**)	0.030	0.030	^	245	415	^^	>27J @ 0ºC
Grade X42 [L290]						290	415		
Grade X46 [L320]						320	435		
Grade X52 [L360]						360	460		
Grade X56 [L390]						390	490		
Grade X60 [L415]						415	520		
Grade X65 [L450]						450	535		
Grade X70 [L485]						485	570		

^ To be specified by the purchaser.
* S is designated as Seamless pipe.
** W is designated as Welded pipe.
^^ The specified minimum elongation, A_f, shall be as determined using the specified equation in API 5L Table 6 – Requitements for the Results of Tensile Tests for PSL 1 Pipe.

A.2.4 Acceptable American structural steel: sheet piles

ASTM A328-2013(R2018)： Steel Sheet Piling

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV	Y_s (N/mm²)	U_s (N/mm²)	ε_L[a] (%)	Impact toughness (J)
		C	P	S					
Grade 39	^	^	0.035	0.04	^	270	450	20	>27J @21°C

Note: [a] The length of test pieces is 200mm.
^ To be specified by the purchaser.

ASTM A857-2019： Steel Sheet Piling, Cold Formed, Light Gage

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L[b] (%)	Impact toughness (J)
		C	P	S					
Grade 30	t ≤ 6.4	0.25	0.035	0.04	^	205	340	23	≥ 27J @ 21°C**
Grade 33	t ≤ 6.4					230	360	22	
Grade 36	t ≤ 6.4					250	365	21	

Note: [b] The length of test pieces is 50mm.
^ To be specified by the purchaser.
** This requirement shall be applied unless specified in the order.

with dimensional and/or mass tolerances in accordance with:-
ASTM A6
or any acceptable steel for cold forming (see A.2.6)

A.2.5 Acceptable American structural steel: solid bars

ASTM A709-2021: Structural steel for bridges

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness or Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>Grade 36 [250]</td><td>3 ≤ t ≤ 100</td><td colspan="8" rowspan="7">Refer to ASTM A709 in Section A.2.1</td></tr>
<tr><td>Grade 50 [345]</td><td>3 ≤ t ≤ 100</td></tr>
<tr><td>Grade 50W [345W]</td><td>3 ≤ t ≤ 100</td></tr>
<tr><td>Grade HPS 50W [HPS 345W]</td><td>3 ≤ t ≤ 100</td></tr>
<tr><td>Grade 50CR [345C]</td><td>3 ≤ t ≤ 50</td></tr>
<tr><td>Grade HPS 70W [HPS 485W]</td><td>3 ≤ t ≤ 100</td></tr>
<tr><td>Grade HPS 100W [HPS 690W]</td><td>3 ≤ t ≤ 100</td></tr>
</table>

with dimensional and/or mass tolerances in accordance with:-
ASTM A6

A.2.6 Acceptable American structural steel: strips for cold formed open sections

ASTM A1011–2018: Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L* (%)	Impact toughness (J)
		C	P	S					
SS Grade 30 [205]	0.6 ≤ t ≤ 6.0	0.25	0.035	0.04	^	205	340	19	^
SS Grade 33 [230]		0.25	0.035	0.04		230	360	18	
SS Grade 36 [250] Type 1		0.25	0.035	0.04		250	365	17	
SS Grade 36 [250] Type 2		0.25	0.035	0.04		250	400-550	16	
SS Grade 40 [275]		0.25	0.035	0.04		275	380	16	
SS Grade 45 [310] Type 1		0.25	0.035	0.04		310	410	14	
SS Grade 45 [310] Type 2		0.02 - 0.08	0.03 – 0.07	0.025		310 - 410	410	15	
SS Grade 50 [340]		0.25	0.035	0.04		340	450	12	
SS Grade 55 [380]		0.25	0.035	0.04		380	480	10	
SS Grade 60 [410]		0.25	0.035	0.04		410	520	9	
SS Grade 70 [480]		0.25	0.035	0.04		480	585	8	

^ To be specified by the purchaser.
* Elongation in 200mm specimen.

ASTM A1008–2021: Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
SS Grade 25 [170]	0.6 ≤ t ≤ 8.0	0.20	0.035	0.035	^	170	290	26	^
SS Grade 30 [205]		0.20	0.035	0.035		205	310	24	
SS Grade 33 [230] Type 1		0.20	0.035	0.035		230	330	22	
SS Grade 33 [230] Type 2		0.15	0.20	0.035		230	330	22	
SS Grade 40 [275] Type 1		0.20	0.035	0.035		275	360	20	

(To be continued)

(Continued)

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness or Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>SS Grade 40 [275] Type 2</td><td rowspan="6">0.6 ≤ t ≤ 8.0</td><td>0.15</td><td>0.20</td><td>0.035</td><td rowspan="6">^</td><td>275</td><td>360</td><td>20</td><td rowspan="6">^</td></tr>
<tr><td>SS Grade 45 [310]</td><td>0.20</td><td>0.070</td><td>0.025</td><td>310</td><td>410</td><td>20</td></tr>
<tr><td>SS Grade 50 [340]</td><td>0.20</td><td>0.035</td><td>0.035</td><td>340</td><td>450</td><td>18</td></tr>
<tr><td>SS Grade 60 [410]</td><td>0.20</td><td>0.035</td><td>0.035</td><td>410</td><td>520</td><td>12</td></tr>
<tr><td>SS Grade 70 [480]</td><td>0.20</td><td>0.035</td><td>0.035</td><td>480</td><td>585</td><td>6</td></tr>
<tr><td>SS Grade 80 [550]</td><td>0.20</td><td>0.035</td><td>0.035</td><td>550</td><td>565</td><td>^</td></tr>
</table>

^ To be specified by the purchaser.

ASTM A792–2021: Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness or Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>SS Grade 33 [230]</td><td rowspan="11">0.6 ≤ t ≤ 8.0</td><td>0.20</td><td>0.04</td><td>0.04</td><td rowspan="11">^</td><td>230</td><td>310</td><td>20</td><td rowspan="11">^</td></tr>
<tr><td>SS Grade 37 [255]</td><td>0.20</td><td>0.10</td><td>0.04</td><td>255</td><td>360</td><td>18</td></tr>
<tr><td>SS Grade 40 [275]</td><td>0.25</td><td>0.10</td><td>0.04</td><td>275</td><td>380</td><td>16</td></tr>
<tr><td>SS Grade 50 [340] Class 1</td><td rowspan="3">0.25</td><td rowspan="3">0.20</td><td rowspan="3">0.04</td><td rowspan="3">340</td><td>450</td><td rowspan="3">12</td></tr>
<tr><td>SS Grade 50 [340] Class 2</td><td>^</td></tr>
<tr><td>SS Grade 50 [340] Class 4</td><td>410</td></tr>
<tr><td>SS Grade 60 [410]</td><td>0.25</td><td>0.20</td><td>0.04</td><td>410</td><td>480</td><td>10</td></tr>
<tr><td>SS Grade 70 [480]</td><td>0.25</td><td>0.20</td><td>0.04</td><td>480</td><td>550</td><td>9</td></tr>
<tr><td>SS Grade 80 [550] Class 1</td><td>0.20</td><td>0.04</td><td>0.04</td><td rowspan="3">550</td><td rowspan="3">570</td><td>^</td></tr>
<tr><td>SS Grade 80 [550] Class 2</td><td>0.02</td><td>0.05</td><td>0.02</td><td>^</td></tr>
<tr><td>SS Grade 80 [550] Class 3</td><td>0.20</td><td>0.04</td><td>0.04</td><td>3</td></tr>
</table>

^ To be specified by the purchaser.

ASTM A875–2021: Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
SS Grade 33 [230]	0.6 ≤ t ≤ 8.0	0.20	0.04	0.04	^	230	310	20	^
SS Grade 37 [255]		0.20	0.10			255	360	18	
SS Grade 50 [340] Class 1		0.25	0.20			340	450	12	
SS Grade 50 [340] Class 2		0.25	0.20			340	^	12	
SS Grade 50 [340] Class 3		0.25	0.04			340	480	12	
SS Grade 80 [550]		0.20	0.04			550	570	^	

^ To be specified by the purchaser.

with dimensional and/or mass tolerances in accordance with:-

- ASTM A924
- ASTM A568

A.2.7 Acceptable American strips for cold-formed steel profiled sheetings

ASTM A653-2020: Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness or Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>SS Grade 33 [230]</td><td rowspan="13">0.35 ≤ t ≤ 1.5</td><td>0.20</td><td>0.10</td><td>0.04</td><td rowspan="13">^</td><td>230</td><td>310</td><td>20</td><td rowspan="13">^</td></tr>
<tr><td>SS Grade 37 [255]</td><td>0.20</td><td>0.10</td><td>0.04</td><td>255</td><td>360</td><td>18</td></tr>
<tr><td>SS Grade 40 [275]</td><td>0.25</td><td>0.10</td><td>0.04</td><td>275</td><td>380</td><td>16</td></tr>
<tr><td>SS Grade 50 [340] Class 1</td><td rowspan="4">0.25</td><td>0.20</td><td rowspan="4">0.04</td><td rowspan="4">340</td><td>450</td><td rowspan="4">12</td></tr>
<tr><td>SS Grade 50 [340] Class 2</td><td>0.20</td><td>^</td></tr>
<tr><td>SS Grade 50 [340] Class 3</td><td>0.04</td><td>480</td></tr>
<tr><td>SS Grade 50 [340] Class 4</td><td>0.20</td><td>410</td></tr>
<tr><td>SS Grade 55 [380]</td><td>0.25</td><td>0.04</td><td>0.04</td><td>380</td><td>480</td><td>11</td></tr>
<tr><td>SS Grade 60 [410]</td><td>0.25</td><td>0.04</td><td>0.04</td><td>410</td><td>480</td><td>10</td></tr>
<tr><td>SS Grade 70 [480]</td><td>0.25</td><td>0.04</td><td>0.04</td><td>480</td><td>550</td><td>9</td></tr>
<tr><td>SS Grade 80 [550] Class 1</td><td>0.20</td><td>0.04</td><td>0.04</td><td rowspan="3">550</td><td rowspan="3">570</td><td>^</td></tr>
<tr><td>SS Grade 80 [550] Class 2</td><td>0.02</td><td>0.05</td><td>0.02</td><td>^</td></tr>
<tr><td>SS Grade 80 [550] Class 3</td><td>0.20</td><td>0.04</td><td>0.04</td><td>3</td></tr>
</table>

^ To be specified by the purchaser.

ASTM A1046-2019: Steel Sheet, Zinc-Aluminum-Magnesium Alloy-Coated by the Hot-Dip Process

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness or Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L* (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>SS Grade 33 [230]</td><td rowspan="11">0.35 ≤ t ≤ 1.5</td><td>0.20</td><td>0.04</td><td rowspan="11">0.04</td><td rowspan="11">^</td><td>230</td><td>310</td><td>20</td><td rowspan="11">^</td></tr>
<tr><td>SS Grade 37 [255]</td><td>0.20</td><td>0.10</td><td>255</td><td>360</td><td>18</td></tr>
<tr><td>SS Grade 40 [275]</td><td>0.25</td><td>0.10</td><td>275</td><td>380</td><td>16</td></tr>
<tr><td>SS Grade 50 [340] Class 1</td><td rowspan="3">0.25</td><td>0.20</td><td rowspan="3">340</td><td>450</td><td rowspan="3">12</td></tr>
<tr><td>SS Grade 50 [340] Class 2</td><td>0.20</td><td>^</td></tr>
<tr><td>SS Grade 50 [340] Class 3</td><td>0.04</td><td>480</td></tr>
<tr><td>SS Grade 50 [340] Class 4</td><td></td><td>0.20</td><td></td><td>410</td><td></td></tr>
<tr><td>SS Grade 55 [380]</td><td>0.25</td><td>0.04</td><td>380</td><td>480</td><td>11</td></tr>
<tr><td>SS Grade 60 [410]</td><td>0.25</td><td>0.04</td><td>410</td><td>490</td><td>10</td></tr>
<tr><td>SS Grade 70 [480]</td><td>0.25</td><td>0.04</td><td>480</td><td>550</td><td>9</td></tr>
<tr><td>SS Grade 80 [550]</td><td>0.20</td><td>0.04</td><td>550</td><td>570</td><td>^</td></tr>
</table>

^ To be specified by the purchaser.
* Elongation in 50mm specimen.

with dimensional and/or mass tolerances in accordance with:
ASTM A 924

A.2.8 Acceptable American stud connectors

ANSI/AWS D1.1-2020: Structural welding code - steel

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L* (%)	Reduction of area (%)
		C	P	S					
Type A	^	^	^	^	^	340	420	14	50
Type B	^	^	^	^	^	350	420	15	50
Type C	^	^	^	^	^	^	552	^	^

^ To be specified by the purchaser.
* Elongation in 50mm specimen.

A.2.9 Acceptable American non-preloaded bolting assemblies

ASTM A193-2020: Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

Steel type	Grade	Thickness or Diameter (mm)	Y_s* (N/mm^2)	U_s (N/mm^2)	ε_L** (%)	Reduction of Area Min (%)
Ferritic steel	B5	D ≤ 100	550	690	16	50
	B6	D ≤ 100	585	760	15	50
	B6X	D ≤ 100	485	620	16	50
	B7	D ≤ 64	720	860	16	50
		64 < D ≤ 100	655	795	16	50
		100 < D ≤ 180	515	690	18	50
	B7M	D ≤ 100	550	690	18	50
		100 < D ≤ 180	515	690	18	50
	B16	D ≤ 64	725	860	18	50
		64 < D ≤ 100	655	760	17	45
		100 < D ≤ 200	585	690	16	45
Austenitic steel	B8, B8M, B8P, B8LN, B8MLN and B8CLN (Class 1 and 1D)	^	205	515	30	50
	B8C and B8T (Class 1)	^	205	515	30	50
	B8A, B8MLCuNA, B8CLNA, B8MA, B8PA, B8TA, B8MLNA, B8NA, B8MNA and B8CA (Class 1A)	^	205	515	30	50
	B8N, N8MN, B8MLCuN (Class 1B and 1D)	^	240	550	30	40
	B8R (Class 1C and 1D)	^	380	690	35	55
	B8RA (Class 1C)	^	380	690	35	55
	B8S (Class 1C and 1D)	^	345	655	35	55
	B8SA (Class 1C)	^	345	655	35	55
	B8, B8C, B8P, B8T and B8N (Class 2)	D ≤ 20	690	860	12	35
		20 < D ≤ 24	550	795	15	35
		24 < D ≤ 30	450	725	20	35
		30 < D ≤ 36	345	690	28	45
	B8M, B8MN and B8MLCuN (Class 2)	D ≤ 20	655	760	15	45
		20 < D ≤ 24	550	690	20	45
		24 < D ≤ 30	450	655	25	45
		30 < D ≤ 36	345	620	30	45
	B8 and B8M2 (Class 2B)	D ≤ 48	515	655	25	40
		48 < D ≤ 64	450	620	30	40
		64 < D ≤ 72	380	550	30	40
	B8M3 (Class 2C)	D ≤ 48	450	585	30	60
		48 < D	415	585	30	60

^ To be specified by the purchaser.
* 0.2% offset from elastic strain

ASTM A307-2021: Carbon Steel Bolts, Studs and Threaded Rod 60000 PSI Tensile Strength

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
Grade A	^	0.30	0.040	0.050	0.55	^	414	18	^
Grade B	^						414 - 690		

^ To be specified by the purchaser.

ASTM F3125-2021: Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength

Grade	Type	Chemical composition (%)			Diameter range(mm)	Y_s (N/mm²)	U_s (N/mm2)	ε_L(%)	Reduction of Area
		C	P	S					Min (%)
A325,A325M, F1852	Type 1	0.30 ~ 0.52	0.035	0.04	M12 ~ M36	660	830	14	35
	Type 3	0.33 ~ 0.40	0.035	0.04					
A490,A490M, F2280	Type 1	0.30 ~ 0.48*	0.035	0.04		940	1040	14	40
	Type 3	0.30 ~ 0.53	0.035	0.04					

* Carbon requirement is 0.35 - 0.53 for 25.4 mm - 12.7 mm. and M36 diameter bolts

ASTM A449-2014(R2020): Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120 / 105 / 90 ksi Minimum Tensile Strength, General Use

Grade	Material or Class	Chemical composition (%)			Diameter range (mm)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Reduction of Area Min (%)
		C	P	S					
Type 1 (Medium carbon alloy steel)	Carbon Steel	0.28 ~ 0.55	0.048	0.058	6.4 ~ 24.4	635	830	14	35
	Boron Steel		0.048	0.058					
	Alloy Steel		0.040	0.045					
	Alloy Boron Steel		0.040	0.045	24.4 ~ 38.1	560	725		
Type 3 (Weathering steel)	A	0.31 ~ 0.42	0.040	0.045					
	B	0.36 ~ 0.50	0.06 ~ 0.125						
	C	0.14 ~ 0.25	0.040		38.1 ~ 76.2	400	620		
	D	0.14 ~ 0.25	0.040						
	E	0.18 ~ 0.27	0.040						
	F	0.19 ~ 0.25	0.040						

ASTM A563 REV A:2021: Carbon and Alloy Steel Nuts

Grade	Thickness or Diameter (mm)	Chemical composition (%)			σ_p* (N/mm^2)	ε_L (%)
		C	P	S		
A	6.35 ~ 101.6	0.55	0.12	0.15	552 ~ 689*** 414 ~ 517****	^
B	6.35 ~ 25.4 28.575 ~ 38.1	0.55	0.12	0.15	648 ~ 827*** 483 ~ 689****	
C	6.35 ~ 101.6	0.55	0.12	0.15	896 ~ 993	
D	6.35 ~ 101.6	0.55	0.04	0.05	930 ~ 1034	
DH	6.35 ~ 101.6	0.20 ~ 0.55	0.04	0.05	1034 ~ 1207	
8S	12 ~ 36	0.55	0.12	0.15	1075*** ^****	
10S	12 ~ 36	0.20 ~ 0.55	0.04	0.05	1245*** 1165****	
C3	6.35 ~ 101.6	0.33 ~ 0.40**	0.035**	0.040**	993	
DH3	6.35 ~ 101.6	0.20 ~ 0.53	0.035	0.040	1034 ~ 1207*** 1034****	
8S3	12 ~ 36	0.33 ~ 0.40**	0.035**	0.040**	1075*** ^****	
10S3	12 ~ 36	0.20 ~ 0.53	0.035	0.040	1245*** 1165	

^ To be specified by the purchaser.
* Proof load stress performed in accordance with requirements of codified test methods: ASTM F606.
** Use composition A values.
*** Is Non-Zinc-Coated Nuts.
**** Is Zinc-Coated Nuts.

ASTM A194 2022: Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Y_s * (N/mm^2)	ε_L (%)
		C	P	S		
1	12 ~ 36	0.15 min	0.040	0.050	825 ~ 895	^
2		0.40 min	0.040	0.050	930 ~ 1035	
2HM		0.40 min	0.040	0.050	930 ~ 1035	
3		0.10 min	0.040	0.030	1035 ~ 1205	
6		0.08 ~ 0.15	0.040	0.030	930 ~ 1035	
6F		0.15	0.060	0.15 min	930 ~ 1035	
7		0.38 ~ 0.48	0.035	0.040	1035 ~ 1205	
7M		0.38 – 0.48	0.035	0.040	930 - 1035	
16		0.36 – 0.47	0.035	0.040	1035 - 1205	

^ To be specified by the purchaser.
* Proof load stress performed in accordance with requirements of codified test methods: ASTM F606.

ASTM F436M–2019 Standard Specification for Hardened Steel Washers [Metric]

Grade	Thickness or Diameter (mm)	Chemical composition (%)			U_s (N/mm^2)	ε_L (%)
		C	P	S		
Type 1 (circular) *	3.1≤t≤8.7	^	0.04	0.05	^	
Type 3 (circular)	3.1≤t≤8.7	^	0.04	0.05	^	
Type 1 (beveled)	7.5≤t≤8.5	^	0.04	0.05	^	
Type 3 (beveled)	7.5≤t≤8.5	^	0.04	0.05	^	

^ To be specified by the purchaser.
* Type 1 carbon steel.
** Type 3 weathering steel.

A.2.10 Acceptable American preloaded bolting assemblies

ASTM F3125-2021: Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength

Grade	Type	Chemical composition (%)			Diameter range(mm)	Y_s (N/mm²)	U_s (N/mm2)	ε_L(%)	Reduction of Area
		C	P	S					Min (%)
A325,A325M, F1852	*Refer to ASTM F3125 in Section A.2.9*								
A490,A490M, F2280									

ASTM A354-2011(E2017) (E2018): Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

Material or Class	Diameter range (mm)	Chemical composition (%)			Grade	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Reduction of Area Min (%)
		C	P	S					
Alloy Steel	D < 38.1	0.28 ~ 0.55	0.040	0.045	BC	750	860	16	50
	38.1 ≤ D	0.33 ~ 0.55	0.040	0.045		685	795	16	45
Alloy Boron Steel	D < 38.1	0.28 ~ 0.50	0.045	0.045	BD	900	1035	14	40
	38.1 ≤ D	0.35 ~ 0.55	0.045	0.045					

ASTM A563 REV A:2021: Carbon and Alloy Steel Nuts

Grade	Thickness or Diameter (mm)	Chemical composition (%)			σ_p* (N/mm²)	ε_L (%)
		C	P	S		
A	6.35 ~ 101.6	*Refer to ASTM A563 in Section A.2.9*				
B	6.35 ~ 25.4 28.575 ~ 38.1					
C	6.35 ~ 101.6					
D	6.35 ~ 101.6					
DH	6.35 ~ 101.6					
8S	12 ~ 36					
10S	12 ~ 36					
C3	6.35 ~ 101.6					
DH3	6.35 ~ 101.6					
8S3	12 ~ 36					
10S3	12 ~ 36					

ASTM F436M–2019 Standard Specification for Hardened Steel Washers [Metric]

Grade	Thickness or Diameter (mm)	Chemical composition (%)			U_s (N/mm²)	ε_L (%)
		C	P	S		
Type 1 (circular)	*Refer to ASTM F436M in Section A.2.9*					
Type 3 (circular)						
Type 1 (beveled)						
Type 3 (beveled)						

A.2.11 Acceptable American welding consumables

AWS A5.1-2012: Carbon Steel Electrodes for Shielded Metal Arc-Welding

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>E4310</td><td>3 ~ 12</td><td>0.20</td><td>^</td><td>^</td><td rowspan="7">330</td><td rowspan="9">430</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4311</td><td>3 ~ 12</td><td>0.20</td><td>^</td><td>^</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4312</td><td>3 ~ 12</td><td>0.20</td><td>^</td><td>^</td><td>17</td><td>^</td></tr>
<tr><td>E4313</td><td>3 ~ 12</td><td>0.20</td><td>^</td><td>^</td><td>17</td><td>^</td></tr>
<tr><td>E4318</td><td>3 ~ 12</td><td>0.03</td><td>0.025</td><td>0.015</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4319</td><td>3 ~ 12</td><td>0.20</td><td>^</td><td>^</td><td>22</td><td>≥ 27J @ -20⁰C</td></tr>
<tr><td>E4320</td><td>6 ~ 12</td><td>0.20</td><td>^</td><td>^</td><td>22</td><td>^</td></tr>
<tr><td>E4322</td><td>6 ~ 12</td><td>^</td><td>^</td><td>^</td><td>^</td><td>^</td><td>^</td></tr>
<tr><td>E4327</td><td>6 ~ 12</td><td>0.20</td><td>^</td><td>^</td><td>330</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4914</td><td>3 ~ 12</td><td>0.15</td><td>0.035</td><td>0.035</td><td rowspan="4">400</td><td rowspan="9">490</td><td>17</td><td>^</td></tr>
<tr><td>E4915</td><td>3 ~ 12</td><td>0.15</td><td>0.035</td><td>0.035</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4916</td><td>3 ~ 12</td><td>0.15</td><td>0.035</td><td>0.035</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4918</td><td>3 ~ 12</td><td>0.15</td><td>0.035</td><td>0.035</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4918M</td><td>3 ~ 12</td><td>0.12</td><td>0.030</td><td>0.020</td><td>370 - 500</td><td>24</td><td>≥ 67J @ -30⁰C</td></tr>
<tr><td>E4924</td><td>6 ~ 12</td><td>0.15</td><td>0.035</td><td>0.035</td><td rowspan="4">400</td><td>17</td><td>^</td></tr>
<tr><td>E4927</td><td>6 ~ 12</td><td>0.15</td><td>0.035</td><td>0.035</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
<tr><td>E4928</td><td>6 ~ 12</td><td>0.15</td><td>0.035</td><td>0.035</td><td>22</td><td>≥ 27J @ -20⁰C</td></tr>
<tr><td>E4948</td><td>6 ~ 10</td><td>0.15</td><td>0.035</td><td>0.035</td><td>22</td><td>≥ 27J @ -30⁰C</td></tr>
</table>

^ To be specified by the purchaser.

A.3 Acceptable Japanese steel materials

A.3.1 Acceptable Japanese structural steel: plates

JIS G 3106-2020: Rolled steels for welded structure

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness** (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV*** (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C (Class)</th><th>P</th><th>S</th></tr>
<tr><td rowspan="6">SM400A
SM400B
SM400C</td><td>t ≤ 5</td><td rowspan="6">t ≤ 50:
0.23 (A)
0.20 (B)
0.18 (C)

t > 50:
0.25 (A)
0.22 (B)
0.18 (C)</td><td rowspan="6">0.035</td><td rowspan="6">0.035</td><td rowspan="6">t ≤ 50:
0.38

50 < t ≤ 100:
0.40</td><td>245</td><td rowspan="6">400 ~ 510</td><td>23</td><td rowspan="6">SM400B
≥ 27J @ 0⁰C

SM400C
≥ 47J @ 0⁰C</td></tr>
<tr><td>5 < t ≤ 16</td><td>245</td><td>18</td></tr>
<tr><td>16 < t ≤ 40</td><td>235</td><td>22</td></tr>
<tr><td>40 < t ≤ 75</td><td>215</td><td>24</td></tr>
<tr><td>75 < t ≤ 100</td><td>215</td><td>24</td></tr>
<tr><td>100 < t ≤ 150</td><td>205*</td><td>24</td></tr>
<tr><td rowspan="6">SM490A
SM490B
SM490C</td><td>t ≤ 5</td><td rowspan="6">t ≤ 50:
0.20 (A)
0.18 (B)
0.18 (C)

t > 50:
0.22 (A)
0.20 (B)
0.18 (C)</td><td rowspan="6">0.035</td><td rowspan="6">0.035</td><td rowspan="6">t ≤ 50:
0.38

50 < t ≤ 100:
0.40</td><td>325</td><td rowspan="6">490 ~ 610</td><td>22</td><td rowspan="6">For SM490B
≥ 27J @ 0⁰C

For SM490C
≥ 47J @ 0⁰C</td></tr>
<tr><td>5 < t ≤ 16</td><td>325</td><td>17</td></tr>
<tr><td>16 < t ≤ 40</td><td>315</td><td>21</td></tr>
<tr><td>40 < t ≤ 75</td><td>295</td><td>23</td></tr>
<tr><td>75 < t ≤ 100</td><td>295</td><td>23</td></tr>
<tr><td>100 < t ≤ 150</td><td>285*</td><td>23</td></tr>
<tr><td rowspan="5">SM490YA
SM490YB</td><td>t ≤ 5</td><td rowspan="5">0.20</td><td rowspan="5">0.035</td><td rowspan="5">0.035</td><td rowspan="5">t ≤ 50:
0.38

50 < t ≤ 100:
0.40</td><td>365</td><td rowspan="5">490 ~ 610</td><td>19</td><td rowspan="5">For
SM490YB
≥ 27J @ 0⁰C</td></tr>
<tr><td>5 < t ≤ 16</td><td>365</td><td>15</td></tr>
<tr><td>16 < t ≤ 40</td><td>355</td><td>19</td></tr>
<tr><td>40 < t ≤ 75</td><td>335</td><td>21</td></tr>
<tr><td>75 < t ≤ 100</td><td>325</td><td>21</td></tr>
<tr><td rowspan="5">SM520B
SM520C</td><td>t ≤ 5</td><td rowspan="5">0.20</td><td rowspan="5">0.035</td><td rowspan="5">0.035</td><td rowspan="5">t < 50:
0.40

50 < t ≤ 100:
0.42</td><td>365</td><td rowspan="5">520 ~ 640</td><td>19</td><td rowspan="5">For SM520B
≥ 27J @ 0⁰C

For SM520C
≥ 47J @ 0⁰C</td></tr>
<tr><td>5 < t ≤ 16</td><td>365</td><td>15</td></tr>
<tr><td>16 < t ≤ 40</td><td>355</td><td>19</td></tr>
<tr><td>40 < t ≤ 75</td><td>335</td><td>21</td></tr>
<tr><td>75 < t ≤ 100</td><td>325</td><td>21</td></tr>
<tr><td rowspan="5">SM570</td><td>t ≤ 16</td><td rowspan="5">0.18</td><td rowspan="5">0.035</td><td rowspan="5">0.035</td><td rowspan="5">t ≤ 50:
0.44

50 < t ≤ 100:
0.47</td><td>460</td><td rowspan="5">570 ~ 720</td><td>19</td><td rowspan="5">≥ 47J @ -5⁰C</td></tr>
<tr><td>16 < t ≤ 20</td><td>460</td><td>26</td></tr>
<tr><td>20 < t ≤ 40</td><td>450</td><td>20</td></tr>
<tr><td>40 < t ≤ 75</td><td>430</td><td>20</td></tr>
<tr><td>75 < t ≤ 100</td><td>420</td><td>20</td></tr>
</table>

^ To be specified by the purchaser.
* Not applicable to Class C.
** Applicable thickness for steel plates:
t ≤ 450 mm: SM400A.
t ≤ 300 mm: SM490A.
t ≤ 250 mm: SM400B, SM400C, SM490B and SM490C.
t ≤ 150 mm: SM490YA, SM490YB, SM520B, SM520C and SM570.
*** General requirement for CEV according to JIS G 3106:

Thickness of steel product mm	50 mm max.	Over 50 mm up to and include 100 mm	Over 100 mm
Carbon equivalent %	0.44 max.	0.47 max.	As agreed between the purchaser and the manufacturer

.

JIS G 3114-2016: Hot-rolled atmospheric corrosion resisting steels for welded structure

Grade	Thickness** (mm)	Chemical composition (%)			Max. CEV	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
SMA400AW SMA400AP SMA400BW SMA400BP SMA400CW SMA400CP	t ≤ 5	0.18	0.035	0.035	t ≤ 50: 0.44 50 < t ≤ 100: 0.47	245	400 ~ 540	22	SMA400BW SMA400BP ≥ 27J @ 0^{0}C SMA400CW SMA400CP ≥ 47J @ 0^{0}C
	5 < t ≤ 16					245		17	
	16 < t ≤ 40					235		27	
	40 < t ≤ 75					215		23	
	75 < t ≤ 100					215		23	
	100 < t ≤ 160					205*		23	
	160 < t ≤ 200					195*		23	
SMA490AW SMA490AP SMA490BW SMA490BP SMA490CW SMA490CP	t ≤ 5	0.18	0.035	0.035	t ≤ 50: 0.44 50 < t ≤ 100: 0.47	365	490 ~ 610	19	SMA490BW SMA490BP ≥ 27J @ 0^{0}C SMA490CW SMA490CP ≥ 47J @ 0^{0}C
	5 < t ≤ 16					365		15	
	16 < t ≤ 40					355		19	
	40 < t ≤ 75					335		21	
	75 < t ≤ 100					325		21	
	100 < t ≤ 160					305*		21	
	160 < t ≤ 200					295*		21	
SMA570W SMA570P	t ≤ 16	0.18	0.035	0.035	t ≤ 50: 0.44 50 < t ≤ 100: 0.47	460	570 ~ 720	19	≥ 47J @ -5^{0}C
	16 < t ≤ 20					450		26	
	20 < t ≤ 40					450		20	
	40 < t ≤ 75					430		20	
	75 < t ≤ 100					420		20	

* Not applicable to Class C.

JIS G 3136-2012: Rolled steels for building structure

Grade	Thickness** (mm)	Chemical composition (%)			Max. CEV	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
SN400A	6 ≤ t < 12	0.24	0.050	0.050	^	235	400 ~ 510	17	^
	12 ≤ t < 16					235		17	
	16					235		21	
	16 < t ≤ 40					235		23	
	40 < t ≤ 50					215		23	
	50 < t ≤ 100					215		23	
SN400B	6 ≤ t < 12	t ≤ 50: 0.20 50 < t ≤ 100: 0.22	0.030	0.015	0.36	235	400 ~ 510	18	≥ 27J @ 0^{0}C
	12 ≤ t < 16					235 ~ 355		18	
	16					235 ~ 355		22	
	16 < t ≤ 40					235 ~ 355		22	
	40 < t ≤ 50					215 ~ 335		24	
	50 < t ≤ 100					215 ~ 335		24	
SN400C	16	t ≤ 50: 0.20 50 < t ≤ 100: 0.22	0.020	0.008	0.36	235 ~ 355	400 ~ 510	18	≥ 27J @ 0^{0}C
	16 < t ≤ 40					235 ~ 355		22	
	40 < t ≤ 50					215 ~ 335		24	
	50 < t ≤ 100					215 ~ 335		24	

(To be continued)

(Continued)

Grade	Thickness** (mm)	Chemical composition (%)			Max. CEV	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
SN490B	6 ≤ t < 12	t ≤ 50: 0.18 50 < t ≤ 100: 0.20	0.030	0.015	t ≤ 40 0.44 40 < t ≤ 100 0.46	325	490 ~ 610	17	≥ 27J @ 0°C
	12 ≤ t < 16					325 ~ 445		17	
	16					325 ~ 445		21	
	16 < t ≤ 40					325 ~ 445		21	
	40 < t ≤ 50					295 ~ 415		23	
	50 < t ≤ 100					295 ~ 415		23	
SN490C	16	t ≤ 50: 0.18 50 < t ≤ 100: 0.20	0.020	0.008	t ≤ 40 0.44 40 < t ≤ 100 0.46	325 ~ 445	490 ~ 610	21	≥ 27J @ 0°C
	16 < t ≤ 40					325 ~ 445		21	
	40 < t ≤ 50					295 ~ 415		23	
	50 < t ≤ 100					295 ~ 415		23	

^ To be specified by the purchaser.

with dimensional and/or mass tolerances in accordance with:
JIS G 3193

A.3.2 Acceptable Japanese structural steel: sections

JIS G 3106-2020: Rolled steels for welded structure - Refer to **Section A.3.1**

JIS G 3114-2016: Hot-rolled atmospheric corrosion resisting steels for welded structure - Refer to **Section A.3.1**

JIS G 3136-2012: Rolled steels for building structure - Refer to **Section A.3.1**

with dimensional and/or mass tolerances in accordance with:
JIS G 3192

A.3.3 Acceptable Japanese structural steel: hollow sections

JIS G 3475–2021: Carbon steel tubes for building structure

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
STKN400W	t ≤ 80	0.25	0.030	0.030	0.36	235	400 ~ 540	23	^
STKN400B	t ≤ 12	0.25	0.030	0.015	0.36	235	400 ~ 540	23	>27J @ 0°C
	12 < t ≤ 40					235 ~ 385			
	40 < t ≤ 80					215 ~ 365			
STKN490B	t ≤ 12	0.22	0.030	0.015	0.44	325	490 ~ 640	23	>27J @ 0°C
	12 < t ≤ 40					325 ~ 475			
	40 < t ≤ 80					295 ~ 445			

^ To be specified by the purchaser.

A.3.4 Acceptable Japanese structural steel: sheet piles

JIS A 5523–2021: Weldable hot-rolled steel sheet piles

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
SYW295	^	0.18	0.040	0.040	0.44	295	450	24	>43J @ 0ºC
SYW390	^				0.45	390	490	20	
SYW430	^				0.46	430	510	19	

^ To be specified by the purchaser.

JIS A 5528-2021: Hot rolled steel sheet piles

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
SY295	^	^	0.040	0.040	^	295	450	24	^
SY390	^				^	390	490	20	

^ To be specified by the purchaser.

Or any combination of steel grades manufactured to standards listed under:-

- A.1.6
- A.2.6
- A.4.6
- A.5.6

with dimensional and/or mass tolerances in accordance with:
JIS A 5523
JIS A 5528
Or any acceptable steel for cold forming (see A.3.6)

A.3.5 Acceptable Japanese structural steel: solid bars

JIS G 3106-2020: Rolled steels for welded structure

Grade	Thickness** (mm)	Chemical composition (%)			Max. CEV*** (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C (Class)	P	S					
SM400A SM400B SM400C	t ≤ 5	*Refer to JIS G 3106 in Section A.3.1*							
	5 < t ≤ 16								
	16 < t ≤ 40								
	40 < t ≤ 50								
	50 < t ≤ 75								
	75 < t ≤ 100								
	100 < t ≤ 160	0.25 (A) 0.22 (B) 0.18 (C)	0.035	0.035	-	205*	400 ~ 510	24	SM400B ≥ 27J @ 0°C SM400C ≥ 47J @ 0°C
	160 < t ≤ 200					195*		24	
SM490A SM490B SM490C	t ≤ 5	*Refer to JIS G 3106 in Section A.3.1*							
	5 < t ≤ 16								
	16 < t ≤ 40								
	40 < t ≤ 50								
	50 < t ≤ 75								
	75 < t ≤ 100								
	100 < t ≤ 160	0.22 (A) 0.20 (B) 0.18 (C)	0.035	0..035	-	285*	490 ~ 610	23	For SM490B ≥ 27J @ 0°C For SM490C ≥ 47J @ 0°C
	160 < t ≤ 200					275*		23	
SM490YA SM490YB	t ≤ 5	*Refer to JIS G 3106 in Section A.3.1*							
	5 < t ≤ 16								
	16 < t ≤ 40								
	40 < t ≤ 75								
	75 < t ≤ 100								
SM520B SM520C	t ≤ 5	*Refer to JIS G 3106 in Section A.3.1*							
	5 < t ≤ 16								
	16 < t ≤ 40								
	40 < t ≤ 75								
	75 < t ≤ 100								
SM570	t ≤ 16	*Refer to JIS G 3106 in Section A.3.1*							
	16 < t ≤ 20								
	20 < t ≤ 40								

^ To be specified by the purchaser.
* Not applicable to Class C.
** Applicable thickness for steel plates:
t ≤ 450 mm: SM400A.
t ≤ 300 mm: SM490A.
t ≤ 250 mm: SM400B, SM400C, SM490B and SM490C.
t ≤ 150 mm: SM490YA, SM490YB, SM520B, SM520C and SM570.
*** General requirement for CEV according to JIS G 3106:

Thickness of steel product mm	50 mm max.	Over 50 mm up to and include 100 mm	Over 100 mm
Carbon equivalent %	0.44 max.	0.47 max.	As agreed between the purchaser and the manufacturer

JIS G 3114-2016: Hot-rolled atmospheric corrosion resisting steels for welded structure

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
SMA400AW SMA400AP SMA400BW SMA400BP	t ≤ 5	0.18	0.035	0.035	t ≤ 50: 0.44 50 < t ≤ 100: 0.47	245	400 ~ 540	22	SMA400BW SMA400BP ≥ 27J @ 0^0C SMA400CW SMA400CP ≥ 47J @ 0^0C
	5 < t ≤ 16					245		17	
	16 < t ≤ 40					235		27	
	40 < t ≤ 75					215		23	
	75 < t ≤ 100					215		23	
	100 < t ≤ 160					205*		23	
	160 < t ≤ 200					195*		23	
SMA490AW SMA490AP SMA490BW SMA490BP	t ≤ 5	0.18	0.035	0.035	t ≤ 50: 0.44 50 < t ≤ 100: 0.47	365	490 ~ 610	19	SMA490BW SMA490BP ≥ 27J @ 0^0C SMA490CW SMA490CP ≥ 47J @ 0^0C
	5 < t ≤ 16					365		15	
	16 < t ≤ 40					355		19	
	40 < t ≤ 75					335		21	
	75 < t ≤ 100					325		21	
	100 < t ≤ 160					305*		21	
	160 < t ≤ 200					295*		21	

* Not applicable to Class C.

JIS G 3136-2012: Rolled steels for building structure

Grade	Thickness** (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
SN400A	6 ≤ t < 12	0.24	0.050	0.050	^	235	400 ~ 510	17	^
	12 ≤ t < 16					235		17	
	16					235		21	
	16 < t ≤ 40					235		23	
	40 < t ≤ 50					215		21	
	50 < t ≤ 100					215		23	
SN400B	6 ≤ t < 12	t ≤ 50: 0.20 50 < t ≤ 100: 0.22	0.030	0.015	0.36	235	400 ~ 510	18	≥ 27J @ 0^0C
	12 ≤ t < 16					235 ~ 355		18	
	16					235 ~ 355		22	
	16 < t ≤ 40					235 ~ 355		22	
	40 < t ≤ 50					215 ~ 335		24	
	50 < t ≤ 100					215 ~ 335		24	
SN400C	16	t ≤ 50: 0.20 50 < t ≤ 100: 0.22	0.020	0.008	0.36	235 ~ 355	400 ~ 510	18	≥ 27J @ 0^0C
	16 < t ≤ 40					235 ~ 355		22	
	40 < t ≤ 50					215 ~ 335		24	
	50 < t ≤ 100					215 ~ 335		24	
SN490B	6 ≤ t < 12	t ≤ 50: 0.18 50 < t ≤ 100: 0.20	0.030	0.015	t ≤ 40 0.44 40 < t ≤ 100 0.46	325	490 ~ 610	17	≥ 27J @ 0^0C
	12 ≤ t < 16					325 ~ 445		17	
	16					325 ~ 445		21	
	16 < t ≤ 40					325 ~ 445		21	
	40 < t ≤ 50					295 ~ 415		23	
	50 < t ≤ 100					295 ~ 415		23	

(To be continued)
(Continued)

Grade	Thickness** (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
SN490C	16	t ≤ 50: 0.18 50 < t ≤ 100: 0.20	0.020	0.008	t ≤ 40 0.44 40 < t ≤ 100 0.46	325 ~ 445	490 ~ 610	21	≥ 27J @ 0⁰C
	16 < t ≤ 40					325 ~ 445		21	
	40 < t ≤ 50					295 ~ 415		23	
	50 < t ≤ 100					295 ~ 415		23	

^ To be specified by the purchaser.

with dimensional and/or mass tolerances in accordance with:-
JIS G 3191

A.3.6 Acceptable Japanese structural steel: strips for cold formed open sections

JIS G 3106-2020: Rolled steels for welded structure - Refer to **Section A.3.1**

JIS G 3114-2016: Hot-rolled atmospheric corrosion resisting steels for welded structure - Refer to **Section A.3.1**

JIS G 3136-2012: Rolled steels for building structure - Refer to **Section A.3.1**

JIS G 3350-2021: Light gauge steel sections for general structure

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
SSC400	1.6 ≤ t ≤ 5.0	0.25	0.050	0.050	0.44	245	400 ~ 540	21	^
	5.0 ≤ t ≤ 6.0							17	

^ To be specified by the purchaser.

with dimensional and/or mass tolerances in accordance with:
JIS G 3193

A.3.7 Acceptable Japanese strips for cold-formed profiled sheets

JIS G 3302-2019: Hot-dip zinc-coated steel sheet and strip

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)
		C	P	S			
SGHC	1.6 ~ 6.0	0.15	0.050	0.050	^	^	^
SGH340	1.6 ~ 6.0	0.25	0.200	0.050	245	340	20
SGH400	1.6 ~ 6.0	0.25	0.200	0.050	295	400	18
SGH440	1.6 ~ 6.0	0.25	0.200	0.050	335	440	18
SGH490	1.6 ~ 6.0	0.30	0.200	0.050	365	490	16
SGH540	1.6 ~ 6.0	0.30	0.200	0.050	400	540	16
SGCD1	0.30 ~ 2.3	0.12	0.040	0.040	^	270	32 ~ 38*
SGCD2	0.40 ~ 2.3	0.10	0.030	0.030	^	270	36 ~ 40*
SGCD3	0.60 ~ 2.3	0.08	0.030	0.030	^	270	40 ~ 42*
SGCD4	0.60 ~ 2.3	0.06	0.030	0.030	^	270	42 ~ 44*
SGCH	0.11 ~ 1.0	0.18	0.080	0.050	^	^	^
SGCC	0.19 ~ 3.2	0.15	0.050	0.050	^	^	^
SGC340	0.25 ~ 3.2	0.25	0.200	0.050	245	340	20
SGC400	0.25 ~ 3.2	0.25	0.200	0.050	295	400	18
SGC440	0.25 ~ 3.2	0.25	0.200	0.050	335	440	18
SGC490	0.25 ~ 3.2	0.30	0.200	0.050	365	490	16
SGC570	0.25 ~ 2.0	0.30	0.200	0.050	560	570	^

^ To be specified by the purchaser.
* Details refer to the data provided in the document as arranged in the following table

Grade	Elongation (%)					
	Nominal thickness (mm)					
	$0.25 \le t < 0.40$	$0.40 \le t < 0.60$	$0.60 \le t < 1.0$	$1.0 \le t < 1.6$	$1.6 \le t < 2.5$	$2.5 \le t$
SGCD1	32	34	36	37	38	^
SGCD2	^	36	38	39	40	^
SGCD3	^	^	40	41	42	^
SGCD4	^	^	42	43	44	^

^ Not applicable

JIS G 3317-2019: Hot-dip zinc-5 % aluminium alloy-coated steel sheet and strip

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
		C	P	S			
SZAHC	1.6 ~ 4.5	0.15	0.050	0.050	^	^	^
SZAH340	1.6 ~ 4.5	0.25	0.200	0.050	245	340	20
SZAH400	1.6 ~ 4.5	0.25	0.200	0.050	295	400	18
SZAH440	1.6 ~ 4.5	0.25	0.200	0.050	335	440	18
SZAH490	1.6 ~ 4.5	0.30	0.200	0.050	365	490	16
SZAH540	1.6 ~ 4.5	0.30	0.200	0.050	400	540	16
SZACD1	0.27 ~ 2.3	0.12	0.040	0.040	^	270	32 ~ 38*
SZACD2	0.40 ~ 2.3	0.10	0.030	0.030	^	270	36 ~ 40*
SZACD3	0.60 ~ 2.3	0.08	0.030	0.030	^	270	40 ~ 42*
SZACD4	0.60 ~ 2.3	0.06	0.030	0.030	^	270	42 ~ 44*
SZACH	0.25 ~ 1.0	0.18	0.080	0.050	^	^	^
SZACC	0.25 ~ 2.3	0.15	0.050	0.050	^	^	^
SZAC340	0.25 ~ 2.3	0.25	0.200	0.050	245	340	20
SZAC400	0.25 ~ 2.3	0.25	0.200	0.050	295	400	18
SZAC440	0.25 ~ 2.3	0.25	0.200	0.050	335	440	18
SZA490	0.25 ~ 2.3	0.30	0.200	0.050	365	490	16
SZAC570	0.25 ~ 2.0	0.30	0.200	0.050	560	570	^

^ To be specified by the purchaser.
* Details refer to the data provided in the document as arranged in the following table

Grade	Elongation (%)				
	Nominal thickness (mm)				
	0.25 ≤ t < 0.40	0.40 ≤ t < 0.60	0.60 ≤ t < 1.0	1.0 ≤ t < 1.6	1.6 ≤ t ≤ 2.3
SZACD1	32	34	36	37	38
SZACD2	^	36	38	39	40
SZACD3	^	^	40	41	42
SZACD4	^	^	42	43	44

^ Not applicable

JIS G 3321-2019: Hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
		C	P	S			
SGLHC	1.6 ~ 2.3	0.15	0.050	0.050	^	^	^
SGLHC400	1.6 ~ 2.3	0.25	0.200	0.050	295	400	18
SGLHC490	1.6 ~ 2.3	0.30	0.200	0.050	365	490	16
SGLCC	0.24 ~ 2.3	0.15	0.050	0.050	^	^	^
SGLCD	0.27 ~ 1.6	0.10	0.030	0.030	^	270	27 ~ 33*
SGLCDD	0.40 ~ 1.6	0.080	0.030	0.030	^	270	29 ~ 35*
SGLC400	0.25 ~ 2.3	0.25	0.200	0.050	295	400	16 ~ 18*
SGLC440	0.25 ~ 2.3	0.25	0.200	0.050	335	440	14 ~ 18*
SGLC490	0.25 ~ 2.3	0.30	0.200	0.050	365	490	12 ~ 16*
SGLC570	0.19 ~ 2.0	0.30	0.200	0.050	560	570	^

^ To be specified by the purchaser.
* Details refer to the data provided in the document as arranged in the following table

Grade	Elongation (%)				
	Nominal thickness (mm)				
	$0.25 \le t < 0.40$	$0.40 \le t < 0.60$	$0.60 \le t < 1.0$	$1.0 \le t < 1.6$	$1.6 \le t \le 2.3$
SGLCD	^	27	31	32	33
SGLCDD	^	29	32	34	35
SGLC400	16	17	18	18	18
SGLC440	14	15	16	18	18
SGLC490	12	13	14	16	16

^ Not applicable

A.3.8 Acceptable Japanese stud connectors

JIS B 1198-2011: Headed Studs

Material	Thickness or Diameter (mm)	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
		C	P	S			
Silicon killed steel	^	0.20	0.040	0.040	235	400 ~ 550	20
Aluminium killed steel	^	0.20	0.040	0.040	235	400 ~ 550	20

^ To be specified by the purchaser.

A.3.9 Acceptable Japanese non-preloaded bolting assemblies

JIS B 1051-2014: Mechanical properties of fasteners made of carbon steel and alloy steel- Part 1: Bolts, screws and studs

Grade	Material or treatment	Chemical composition (%)			Y_s* (N/mm²)	U_s (N/mm²)	ε_L (%)
		C	P	S			
4.6	Carbon steel or carbon steel with additives	0.55	0.050	0.060	240	400	22
4.8		0.55	0.050	0.060	^	420	^
5.6		Min: 0.13 Max: 0.55	0.050	0.060	300	500	20
5.8		0.55	0.050	0.060	^	520	^
6.8		Min: 0.15 Max: 0.55	0.050	0.060	^	600	^
8.8	Carbon steel quenched and tempered	Min: 0.25 Max: 0.55	0.025	0.025	^	d ≤ 16 : 800 d > 16 : 830	12
	Carbon steel with additives quenched and tempered	Min: 0.15 Max: 0.40	0.025	0.025			
	Alloy steel quenched and tempered	Min: 0.20 Max: 0.55	0.025	0.025			
9.8	Carbon steel quenched and tempered	Min: 0.25 Max: 0.55	0.025	0.025	^	d ≤ 16 : 900	10
	Carbon steel with additives quenched and tempered	Min: 0.15 Max: 0.40	0.025	0.025			
	Alloy steel quenched and tempered	Min: 0.20 Max: 0.55	0.025	0.025			
10.9	Carbon steel quenched and tempered	Min: 0.25 Max: 0.55	0.025	0.025	^	1040	9
	Carbon steel with additives quenched and tempered	Min: 0.20 Max: 0.55	0.025	0.025			
	Alloy steel quenched and tempered	Min: 0.20 Max: 0.55	0.025	0.025			
12.9	Alloy steel quenched and tempered	Min: 0.30 Max: 0.50	0.025	0.025	^	1220	8
	Carbon steel with additives quenched and tempered	Min: 0.28 Max: 0.50	0.025	0.025			

^ To be specified by the purchaser.
* Lower yield stress or stress at 0.2% non-proportional elongation.

JIS B 1052-2-2014: Mechanical properties of fasteners - Part 2: Nuts with specified proof load values-Coarse thread

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Y_s* (N/mm²)	ε_L (%)
		C	P	S		
04	(Thin nut)	0.58	0.060	0.150	380	^
05	(Thin nut)	0.58	0.048	0.058	500	^
5	≤ 39	0.58	0.060	0.150	580 ~ 630	^
6	≤ 39	0.58	0.060	0.150	670 ~ 720	^
8	≤ 39	0.58	D≤16 0.060 D>16 0.048	D≤16 0.150 D>16 0.058	855 ~ 920	^
9	^	0.58	0.060	0.150	915 ~ 920	^
10	≤ 39	0.58	0.048	0.058	1040 ~ 1060	^
12	≤ 16	0.58	0.048	0.058	1150 ~ 1200	^

^ To be specified by the purchaser.
* Stress under proof load.

A.3.10 Acceptable Japanese preloaded bolting assemblies

JIS B 1186-2013: Sets of high strength hexagon bolt, hexagon nut and plain washers for friction grip joints

Grade	Thickness or Diameter (mm)	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
		C	P	S			
F8T	≤ 30	^	^	^	640	800 ~ 1000	16
F10T	≤ 30	^	^	^	900	1000 ~ 1200	14

^ To be specified by the purchaser.

A.3.11 Acceptable Japanese welding consumables

JIS Z 3211-2008: Covered electrodes for mild steel, high tensile strength steel and low temperature service steel

Grade	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
	C	P	S			
E4303	0.20	^	^	330	430	20
E4310				330	430	20
E4311						
E4312				330	430	16
E4313						
E4316				330	430	20
E4318	0.03	0.025	0.015			
E4319	0.20	^	^	330	430	20
E4320				330	430	20
E4324				330	430	16
E4327				330	430	20
E4340	^	^	^	330	430	20
E4903	0.15	^	^	400	490	20
E4910	0.20	^	^	400	480 ~ 650	20
E4911						
E4912	0.20	0.035	0.035	400	490	16
E4913						
E4914	0.15	0.035	0.035			
E4915	0.15	0.035	0.035	400	490	20
E4916	0.15	0.035	0.035			
E4918	0.15	0.035	0.035			
E4919	0.15	0.035	0.035	400	490	20
E4924				400	490	16
E4927	0.15	0.035	0.035	400	490	20
E4928	0.15	0.035	0.035	400	490	20
E4948						
E5716	0.12	0.030	0.030	490	570	16
E5728						
E4910-1M3	0.12	0.030	0.030	420	490	20
E4910-P1	0.20	0.030	0.030	420	490	20
E4911-1M3	0.12	0.030	0.030	400	490	20
E4915-1M3	0.12	0.030	0.030			
E4916-1M3						
E4918-1M3	0.12	0.030	0.030			
E4919-1M3	0.12	0.030	0.030			
E4920-1M3	0.12	0.030	0.030			

(To be continued)

(Continued)

Grade	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
	C	P	S			
E4924-1	0.15	0.035	0.035	400	490	20
E4927-1M3	0.12	0.030	0.030	400	490	20
E5510-P1	0.20	0.030	0.030	460	550	19
E57J16-N1M1	0.12	0.030	0.030	500	570	16
E57J18-N1M1						
E5916-3M2	0.12	0.030	0.030	490	590	16
E5916-N1M1	0.12	0.030	0.030			
E5918-N1M1						
E59J16-N1M1	0.12	0.030	0.030	500	590	16
E59J18-N1M1						
E6216-3M2	0.12	0.030	0.030	530	620	15
E6216-NIM1	0.12	0.030	0.030			
E6216-N2M1	0.12	0.030	0.030			
E6218-N1M1	0.12	0.030	0.030	530	620	15
E6218-N2M1	0.12	0.030	0.030			
E6916-N3CM1	0.12	0.030	0.030	600	690	14
E6916-N4M3	0.12	0.030	0.030			
E7816-N4CM2	0.12	0.030	0.030	690	780	13
E7816-N5CM3	0.12	0.030	0.030			
E78J16-N4CM2	0.12	0.030	0.030	700	780	13
E78J16-N5CM3	0.12	0.030	0.030			
E78J16-N5M4	0.12	0.030	0.030			
E4916-N1	0.12	0.030	0.030	390	490	20
E4916-N2	0.08	0.030	0.030			
E4916-N3	0.10	0.030	0.030			
E4928-N1	0.12	0.030	0.030			
E5516-N1				460	550	17
E5516-N2	0.12	0.030	0.030	470 ~ 550	550	20
E5518-N2						
E5518-N2M3	0.10	0.020	0.020	460	550	17
E5528-N1	0.12	0.030	0.030			
E6216-N4M1	0.12	0.030	0.030	580	620	15
E7816-N4C2M1	0.12	0.030	0.030	690	780	13
E4916-1	0.15	0.035	0.035	400	490	20
E4918-1	0.15	0.035	0.035			
E4918-N2	0.08	0.030	0.030	390	490	20
E5516-3M3	0.12	0.030	0.030	460	550	17
E5516-3N3	0.10	0.030	0.030			
E5516-N3	0.10	0.030	0.030			
E5518-3M2	0.12	0.030	0.030			
E5518-3M3	0.12	0.030	0.030			
E5518-N3	0.10	0.030	0.030			

(To be continued)

(Continued)

Grade	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
	C	P	S			
E6215-3M2	0.12	0.030	0.030	530	620	15
E6218-3M2	0.12	0.030	0.030	530	620	15
E6218-3M3	0.12	0.030	0.030	530	620	15
E6218-N3M1	0.10	0.030	0.030	540 ~ 620	620	21
E6915-4M2	0.15	0.030	0.030	600	690	14
E6916-4M2	0.15	0.030	0.030	600	690	14
E6918-4M2	0.15	0.030	0.030	600	690	14
E6918-N3M2	0.10	0.030	0.030	610 ~ 690	690	18
E7618-N4M2	0.10	0.030	0.030	680 ~ 760	760	18
E8318-N4C2M2	0.10	0.030	0.030	745 ~ 830	830	16
E4928-N5	0.10	0.025	0.020	390	490	20
E5516-N5	0.12	0.030	0.030	390	490	17
E5518-N5	0.12	0.030	0.030	390	490	17
E5916-N5M1	0.12	0.030	0.030	490	590	16
E6216-N5M1	0.12	0.030	0.030	530	620	15
E6916-N7CM3	0.12	0.030	0.030	600	690	14
E7816-N5M4	0.12	0.030	0.030	690	780	13
E4915-N5	0.05	0.030	0.030	390	490	20
E4916-N5	0.05	0.030	0.030	390	490	20
E4918-N5	0.05	0.030	0.030	390	490	20
E5516-N7	0.12	0.030	0.030	460	550	17
E5518-N7	0.12	0.030	0.030	460	550	17
E7816-N9M3	0.12	0.030	0.030	690	780	13
E4915-N7	0.05	0.030	0.030	390	490	20
E4916-N7	0.05	0.030	0.030	390	490	20
E4918-N7	0.05	0.030	0.030	390	490	20
E5516-N13	0.06	0.025	0.020	460	550	17
E6215-N13L	0.05	0.030	0.030	530	620	15
E49XX-G	^	^	^	400	490	20
E55XX-G	^	^	^	460	550	17
E57XX-G	^	^	^	490	570	16
E57J16-G	^	^	^	500	570	16
E57J18-G	^	^	^	500	570	16

(To be continued)

(Continued)

Grade	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
	C	P	S			
E59J16-G				500	590	16
E59J18-G						
E6210-G				530	620	15
E6211-G						
E6213-G				530	620	12
E6215-G				530	620	15
E6216-G						
E6218-G						
E6910-G				600	690	14
E6911-G						
E6913-G				600	690	11
E6915-G				600	690	14
E6916-G						
E6918-G						
E7610-G	^	^	^	670	760	13
E7611-G						
E7613-G				670	760	11
E7615-G				670	760	13
E7616-G						
E7618-G						
E7816-G				690	780	13
E78J16-G				700	780	13
E78J18-G						
E8310-G				740	830	12
E8311-G						
E8313-G				740	830	10
E8315-G				740	830	12
E8316-G						
E8318-G						

^ To be specified by the purchaser.

A.4 Acceptable Australian/New Zealand steel materials

A.4.1 Acceptable Australian/New Zealand structural steel: plates

AS/NZS 3678-2016: Structural steel – Hot-rolled plates, floor plates and slabs

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness** (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV*** (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td rowspan="8">200</td><td>t ≤ 8</td><td rowspan="8">0.15</td><td rowspan="8">0.030</td><td rowspan="8">0.030</td><td rowspan="8">0.25</td><td>200</td><td rowspan="3">300</td><td rowspan="3">24</td><td rowspan="8">^</td></tr>
<tr><td>8 < t ≤ 12</td><td>200</td></tr>
<tr><td>12 < t ≤ 20</td><td>^</td></tr>
<tr><td>20 < t ≤ 32</td><td>^</td><td rowspan="4">300</td><td rowspan="4">24</td></tr>
<tr><td>32 < t ≤ 50</td><td>^</td></tr>
<tr><td>50 < t ≤ 80</td><td>^</td></tr>
<tr><td>80 < t ≤ 150</td><td>^</td></tr>
<tr><td>150 < t ≤ 200</td><td>^</td><td>290</td><td>23</td></tr>
<tr><td rowspan="8">250</td><td>t ≤ 8</td><td rowspan="8">0.22</td><td rowspan="8">0.040</td><td rowspan="8">0.030</td><td rowspan="8">0.44</td><td>280</td><td rowspan="3">410</td><td rowspan="3">22</td><td rowspan="8">27J</td></tr>
<tr><td>8 < t ≤ 12</td><td>260</td></tr>
<tr><td>12 < t ≤ 20</td><td>250</td></tr>
<tr><td>20 < t ≤ 32</td><td>250</td><td rowspan="4">410</td><td rowspan="4">22</td></tr>
<tr><td>32 < t ≤ 50</td><td>250</td></tr>
<tr><td>50 < t ≤ 80</td><td>240</td></tr>
<tr><td>80 < t ≤ 150</td><td>230</td></tr>
<tr><td>150 < t ≤ 200</td><td>220</td><td>400</td><td>21</td></tr>
<tr><td rowspan="8">300</td><td>t ≤ 8</td><td rowspan="8">0.22</td><td rowspan="8">0.040</td><td rowspan="8">0.030</td><td rowspan="8">0.44</td><td>320</td><td rowspan="3">430</td><td rowspan="3">21</td><td rowspan="8">27J</td></tr>
<tr><td>8 ≤ t ≤ 12</td><td>310</td></tr>
<tr><td>12 < t ≤ 20</td><td>300</td></tr>
<tr><td>20 < t ≤ 32</td><td>280</td><td rowspan="4">430</td><td rowspan="4">21</td></tr>
<tr><td>32 < t ≤ 50</td><td>280</td></tr>
<tr><td>50 < t ≤ 80</td><td>270</td></tr>
<tr><td>80 < t ≤ 150</td><td>260</td></tr>
<tr><td>150 < t ≤ 200</td><td>250</td><td>420</td><td>20</td></tr>
<tr><td rowspan="8">350</td><td>t ≤ 8</td><td rowspan="8">0.22</td><td rowspan="8">0.040</td><td rowspan="8">0.030</td><td rowspan="8">0.48</td><td>360</td><td rowspan="3">450</td><td rowspan="3">20</td><td rowspan="8">27J</td></tr>
<tr><td>8 ≤ t ≤ 12</td><td>360</td></tr>
<tr><td>12 < t ≤ 20</td><td>350</td></tr>
<tr><td>20 < t ≤ 32</td><td>340</td><td rowspan="4">450</td><td rowspan="4">20</td></tr>
<tr><td>32 < t ≤ 50</td><td>340</td></tr>
<tr><td>50 < t ≤ 80</td><td>340</td></tr>
<tr><td>80 < t ≤ 150</td><td>330</td></tr>
<tr><td>150 < t ≤ 200</td><td>320</td><td>450</td><td>19</td></tr>
<tr><td rowspan="6">400</td><td>t ≤ 8</td><td rowspan="6">0.22</td><td rowspan="6">0.040</td><td rowspan="6">0.030</td><td rowspan="6">0.48</td><td>400</td><td rowspan="3">480</td><td rowspan="3">18</td><td rowspan="6">40J</td></tr>
<tr><td>8 ≤ t ≤ 12</td><td>400</td></tr>
<tr><td>12 < t ≤ 20</td><td>380</td></tr>
<tr><td>20 < t ≤ 32</td><td>360</td><td rowspan="3">480</td><td rowspan="3">18</td></tr>
<tr><td>32 < t ≤ 50</td><td>360</td></tr>
<tr><td>50 < t ≤ 80</td><td>360</td></tr>
</table>

(To be continued)

(Continued)

Grade	Thickness** (mm)	Chemical composition (%)			Max. CEV*** (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
450	t ≤ 8	0.22	0.040	0.030	0.48	450	520	16	40J
	8 ≤ t ≤ 12					450			
	12 < t ≤ 20					450			
	20 < t ≤ 32					420	500	18	
	32 < t ≤ 50					400			
WR350	t ≤ 8	0.14	0.160	0.030	^	340	450	20	27J
	8 ≤ t ≤ 12					340			
	12 < t ≤ 20					340			
	20 < t ≤ 32					340			
	32 < t ≤ 50					340			
	50 < t ≤ 80					340			

^ To be specified by the purchaser.

with dimensional and/or mass tolerances in accordance with:
AS/NZS 1365*

* Plates are rolled on continuous mills. If plates are rolled on reversing mills, width of plate should be less than 2.7 m.

Or steel grades manufactured to:-

AS 1548-2008

- PT430N
- PT430NL0
- PT430NL20
- PT430NL40
- PT430NR
- PT430NRL0
- PT430NRL20
- PT430NRL40
- PT430T
- PT430TL0
- PT430TL20
- PT430TL40
- PT460N
- PT460NL0
- PT460NL20
- PT460NL40
- PT460NL50
- PT460NR
- PT460NRL0
- PT460NRL20
- PT460NRL40
- PT460NRL50
- PT460T
- PT460TL0
- PT460TL20
- PT460TL40
- PT460TL50
- PT490N
- PT490NL20
- PT490NL40
- PT490NL50
- PT490NR
- PT490NRL20
- PT490NRL40
- PT490NRL50
- PT490T
- PT490TL20
- PT490TL40
- PT490TL50
- PT540T
- PT540TL20
- PT540TL40
- PT540TL50

A.4.2 Acceptable Australian/New Zealand structural steel sections

Any combination of steel grades manufactured to:-

AS/NZS 3679.1-2016

- 300L0
- 300L15
- 300S0
- 350L0
- 350S0

A.4.3 Acceptable Australian/New Zealand structural steel: hollow sections

Any combination of steel grades manufactured to:-

AS/NZS 1163-2016

- C250L0
- C350L0
- C450L0

A.4.4 Acceptable Australian/New Zealand structural steel: sheet piles

Any certified steel for cold forming (see **A.4.6**)

A.4.5 Acceptable Australian/New Zealand structural steel: solid bars

Hot rolled steel bars manufactured to:-

AS/NZS 3679.1

A.4.6 Acceptable Australian/New Zealand structural steel: strips for cold formed open sections

Any combination of steel grades manufactured to:-
AS 1397-2011

- G250
- G300
- G350
- G450
- G500
- G550

with dimensional and/or mass tolerances in accordance with:-
AS/NZS 1365

Or any combination of steel grades manufactured to:-
AS/NZS 1595-1998

- CA 220
- CA 260
- CW 300
- CA 350
- CA 500

with dimensional and/or mass tolerances in accordance with:-
AS/NZS 1365-1996*

A.4.7 Acceptable Australian/New Zealand strips for cold-formed profiled sheets

Any combination of steel grades manufactured to:-

AS 1397-2011

- 250
- 300
- 350
- 450
- 500
- 550

with dimensional and/or mass tolerances in accordance with:-

AS/NZS 1365

A.4.8 Acceptable Australian/New Zealand stud connectors

Shear stud connectors manufactured to:-

AS/NZS 1554.2*

NOTE *Stud diameter should be at least 12.7 mm.

A.4.9 Acceptable Australian/New Zealand non-preloaded bolting assemblies

Bolts manufactured to:-

AS/NZS 1252.1
AS/NZS 1252.2
AS 4291.1*
AS/NZS 1559

NOTE * Grade 12.9 is non-certified.

Nuts manufactured to:-

AS/NZS 1252.1
AS/NZS 1252.2
AS/NZS 4291.2

Washers manufactured to:-

AS/NZS 1252.1
AS/NZS 1252.2

A.4.10 Acceptable Australian/New Zealand preloaded bolting assemblies

Bolts manufactured to:-

AS/NZS 1252.1
AS/NZS 1252.2
AS 4291.1*

Nuts manufactured to:-

AS/NZS 1252.1
AS/NZS 1252.2
AS/NZS 4291.2

Washers manufactured to:-

AS/NZS 1252.1
AS/NZS 1252.2

A.4.11 Acceptable Australian/New Zealand welding consumables

Welding consumables, which result in all-weld metals meeting material performance requirements in **3.2.1.11**, and manufactured to:-

AS/NZS 1554.1
AS/NZS 4855
AS/NZS 4857*
AS 1858.1**
SNZ AS/NZS 16834
SNZ AS/NZS 14341
SNZ AS/NZS 21952

NOTE *Only grades 55, 62 and 69 are certified.

NOTE **Z is non-certified.

A.5 Acceptable Chinese steel materials

A.5.1 Acceptable Chinese structural steel: plates

GB/T 700-2006 Carbon structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV [a] (%)	Y_s [c] (N/mm^2)	U_s [d] (N/mm^2)	ε_L (%)	Impact toughness [b] (J)
		C	P	S					
Q235	t ≤ 16	0.22 (A) 0.20 (B) 0.17 (C) 0.17 (D)	0.045 (A) 0.045 (B) 0.040 (C) 0.035 (D)	0.050 (A) 0.045 (B) 0.040 (C) 0.035 (D)	0.35	235	370 ~ 500	26	≥ 27J @ 20°C (B) ≥ 27J @ 0°C (C) ≥ 27J @ -20°C (D)
	16 < t ≤ 40					225			
	40 < t ≤ 60				0.38	215		25	
	60 < t ≤ 100					215		24	
	100 < t ≤ 150					195		22	
	150 < t ≤ 200				0.40	185		21	
Q275	t ≤ 16	0.24 (A) 0.21 (B) 0.20 (C) 0.20 (D)	0.045 (A) 0.045 (B) 0.040 (C) 0.035 (D)	0.050 (A) 0.045 (B) 0.040 (C) 0.035 (D)	0.40	275	410 ~ 540	22	≥ 27J @ 20°C (B) ≥ 27J @ 0°C (C) ≥ 27J @ -20°C (D)
	16 < t ≤ 40					265			
	40 < t ≤ 60	0.24 (A) 0.22 (B) 0.20 (C) 0.20 (D)			0.42	255		21	
	60 < t ≤ 100					245		20	
	100 < t ≤ 150					225		18	
	150 < t ≤ 200				0.44	215		17	

Note: a. Values of Max CEV refer to ISO 630-2:2021.
b. Longitudinal test pieces. If temperature is not specified, it depends on the quality level: 20°C for B class, 0°C for C class. Class A steel material has no requirement for toughness.
c. For nominal thickness > 100 mm, lower limit of tensile strength can be decreased by 20 N/mm^2.

GB/T 1591-2018 High strength low alloy structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [e] (%)	Impact toughness [b] (J)
		C	P [g]	S [g]					
Q355	t ≤ 16	0.24 (B) [f] 0.20 (C) 0.20 (D)	0.035 (B) 0.030 (C) 0.025 (D)	0.035 (B) 0.030 (C) 0.025 (D)	0.45	355	470 ~ 630	22	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 34J @-20°C (D)
	16 < t ≤ 40				0.45 [f]	345		22	
	40 < t ≤ 63	0.24 (B) [f] 0.22 (C) 0.22 (D)			0.47	335		21	
	63 < t ≤ 80				0.47	325		20	
	80 < t ≤ 100					315		20	
	100 < t ≤ 150					295	450 ~ 600	18	
	150 < t ≤ 200				0.49 [g]	285	450 ~ 600	17	
	200 < t ≤ 250					275	450 ~ 600	17	
	250 < t ≤ 400				0.49 [a]	265 [a]	450 ~ 600 [a]	17 [a]	
Q390	t ≤ 16	0.20 (B) 0.20 (C) 0.20 (D)	0.035 (B) 0.030 (C) 0.030 (D)	0.035 (B) 0.030 (C) 0.025 (D)	0.45	390	490 ~ 650	21	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 34J @-20°C (D)
	16 < t ≤ 40				0.45 [f]	380		21	
	40 < t ≤ 63				0.47	360		20	
	63 < t ≤ 80				0.48	340		20	
	80 < t ≤ 100					340		20	
	100 < t ≤ 150					320	470 ~ 620	19	

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (Class) (%) C	P[g]	S[g]	Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L[e] (%)	Impact toughness[b] (J)
Q355N	t ≤ 16	0.20 (B) 0.20 (C) 0.20 (D) 0.18 (E) 0.16 (F)	0.035 (B) 0.030 (C) 0.030 (D) 0.025 (E) 0.020 (F)	0.035 (B) 0.030 (C) 0.025 (D) 0.020 (E) 0.010 (F)	0.43	355	470 ~ 630	22	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-40°C (E) ≥ 63J @ 20°C (F) ≥ 55J @ 0°C (F) ≥ 47J @-20°C (F) ≥ 31J @-40°C (F) ≥ 27J @-60°C (F)
	16 < t ≤ 40					345		22	
	40 < t ≤ 63					335		22	
	63 < t ≤ 80				0.45	325		21	
	80 < t ≤ 100					315		21	
	100 < t ≤ 150				0.45	295	450 ~ 600		
	150 < t ≤ 200					285			
	200 < t ≤ 250					275	450 ~ 600	21	
Q390N	t ≤ 16	0.20 (B) 0.20 (C) 0.20 (D) 0.20 (E)	0.035 (B) 0.030 (C) 0.030 (D) 0.025 (E)	0.035 (B) 0.030 (C) 0.025 (D) 0.020 (E)	0.46	390	490 ~ 650	20	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-40°C (E)
	16 < t ≤ 40					380		20	
	40 < t ≤ 63					360		20	
	63 < t ≤ 80				0.48	340		19	
	80 < t ≤ 100					340		19	
	100 < t ≤ 150				0.49	320	470 ~ 620		
	150 < t ≤ 200					310			
	200 < t ≤ 250					300	470 ~ 620	19	
Q420N	t ≤ 16	0.20 (B) 0.20 (C) 0.20 (D) 0.20 (E)	0.035 (B) 0.030 (C) 0.030 (D) 0.025 (E)	0.035 (B) 0.030 (C) 0.025 (D) 0.020 (E)	0.48	420	520 ~ 680	19	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-20°C (E)
	16 < t ≤ 40					400		19	
	40 < t ≤ 63					390		19	
	63 < t ≤ 80				0.50	370		18	
	80 < t ≤ 100					360		18	
	100 < t ≤ 150				0.52	340	500 ~ 650		
	150 < t ≤ 200					330			
	200 < t ≤ 250					320	500 ~ 650	18	
Q460N	t ≤ 16	0.20 (C) 0.20 (D) 0.20 (E)	0.030 (C) 0.030 (D) 0.025 (E)	0.030 (C) 0.025 (D) 0.020 (E)	0.53	460	540 ~ 720	17	≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-20°C (E)
	16 < t ≤ 40					440		17	
	40 < t ≤ 63					430		17	
	63 < t ≤ 80				0.54	410		17	
	80 < t ≤ 100					400		17	
	100 < t ≤ 150				0.55	380	530 ~ 710		
	150 < t ≤ 200					370			
	200 < t ≤ 250					370	530 ~ 690	17	
Q355M	t ≤ 16	0.14[h]	0.035 (B) 0.030 (C) 0.030 (D) 0.025 (E) 0.020 (F)	0.035 (B) 0.030 (C) 0.025 (D) 0.020 (E) 0.010 (F)	0.39	355	470 ~ 630	22	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-40°C (E) ≥ 63J @ 20°C (F) ≥ 55J @ 0°C (F) ≥ 47J @-20°C (F) ≥ 31J @-40°C (F) ≥ 27J @-60°C (F)
	16 < t ≤ 40				0.39	345			
	40 < t ≤ 63				0.40	335	450 ~ 610		
	63 < t ≤ 80				0.45	325	440 ~ 610		
	80 < t ≤ 100					325	440 ~ 600		
	100 < t ≤ 120[k]				0.45	320	430 ~ 590		

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [e] (%)	Impact toughness [b] (J)
		C	P [g]	S [g]					
Q390M	t ≤ 16	0.15 [h]	0.035 (B) 0.030 (C) 0.030 (D) 0.025 (E)	0.035 (B) 0.030 (C) 0.025 (D) 0.020 (E)	0.41	390	490 ~ 650	20	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-40°C (E)
	16 < t ≤ 40				0.43	380			
	40 < t ≤ 63				0.44	360	480 ~ 640		
	63 < t ≤ 80				0.46	340	470 ~ 630		
	80 < t ≤ 100					340	460 ~ 620		
	100 < t ≤ 120 [k]				0.46	335	450 ~ 610		
Q420M	t ≤ 16	0.16 [h]	0.035 (B) 0.030 (C) 0.030 (D) 0.025 (E)	0.035 (B) 0.030 (C) 0.025 (D) 0.020 (E)	0.43	420	520 ~ 680	19	≥ 34J @ 20°C (B) ≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-20°C (E)
	16 < t ≤ 40				0.45	400			
	40 < t ≤ 63				0.46	390	500 ~ 660		
	63 < t ≤ 80				0.47	380	480 ~ 640		
	80 < t ≤ 100					370	470 ~ 630		
	100 < t ≤ 120 [k]				0.47	365	460 ~ 620		
Q460M	t ≤ 16	0.16 [h]	0.030 (C) 0.030 (D) 0.025 (E)	0.030 (C) 0.025 (D) 0.020 (E)	0.45	460	540 ~ 720	17	≥ 34J @ 0°C (C) ≥ 55J @ 20°C (D) ≥ 47J @ 0°C (D) ≥ 40J @-20°C (D) ≥ 63J @ 20°C (E) ≥ 55J @ 0°C (E) ≥ 47J @-20°C (E) ≥ 31J @-20°C (E)
	16 < t ≤ 40				0.46	440			
	40 < t ≤ 63				0.47	430	530 ~ 710		
	63 < t ≤ 80				0.48	410	510 ~ 690		
	80 < t ≤ 100					400	500 ~ 680		
	100 < t ≤ 120 [k]				0.48	385	490 ~ 660		
Q500M	t ≤ 16	0.18	0.030 (C) 0.030 (D) 0.025 (E)	0.030 (C) 0.025 (D) 0.020 (E)	0.47	500	610 ~ 770	17	≥ 55J @ °C (C) ≥ 47J @-20°C (D) ≥ 31J @-40°C (E)
	16 < t ≤ 40				0.47	490			
	40 < t ≤ 63				0.47	480	600 ~ 760		
	63 < t ≤ 80				0.48	460	590 ~ 750		
	80 < t ≤ 100					450	540 ~ 730		
Q550M	t ≤ 16	0.18	0.030 (C) 0.030 (D) 0.025 (E)	0.030 (C) 0.025 (D) 0.020 (E)	0.47	550	670 ~ 830	16	≥ 55J @ °C (C) ≥ 47J @-20°C (D) ≥ 55J @ °C (C) ≥ 47J @-20°C (D)
	16 < t ≤ 40				0.47	540			
	40 < t ≤ 63				0.47	530	620 ~ 810		
	63 < t ≤ 80				0.48	510	600 ~ 790		
	80 < t ≤ 100					500	590 ~ 780		
Q620M	t ≤ 16	0.18	0.030 (C) 0.030 (D) 0.025 (E)	0.030 (C) 0.025 (D) 0.020 (E)	0.48	620	710 ~ 880	15	≥ 31J @-40°C (E) ≥ 55J @ °C (C) ≥ 47J @-20°C (D)
	16 < t ≤ 40				0.48	610			
	40 < t ≤ 63				0.48	600	690 ~ 880		
	63 < t ≤ 80				0.49	580	670 ~ 860		
Q690M	t ≤ 16	0.18	0.030 (C) 0.030 (D) 0.025 (E)	0.030 (C) 0.025 (D) 0.020 (E)	0.49	690	770 ~ 940	14	≥ 31J @-40°C (E) ≥ 55J @ °C (C) ≥ 47J @-20°C (D)
	16 < t ≤ 40				0.49	680			
	40 < t ≤ 63				0.49	670	750 ~ 920		
	63 < t ≤ 80				0.49	650	730 ~ 900		

Note:
a. Only for steel plate of quality level D class.
b. Longitudinal test pieces. If temperature is not specified, it depends on the quality level: 20°C for B class, 0°C for C class, -20°C for D class and -40°C for E class.
c. Only for section steels and steel bars.
d. Only for Q345D steel plates with thickness > 250 mm.
e. Longitudinal test pieces.
f. When nominal thickness > 30 mm: C = 0.22% max, Max. CEV = 0.47% for Q355, Q390.
g. For section steels and steel bars the P and S content can be 0.005% higher, max. CEV of Q355 can be up to 0.54%.
h. For Q355M, Q390M, Q420M and Q460M, the C content of section steels and steel bars can be 0.02% higher.
k. For section steels and steel bars the nominal thickness or diameter ≤ 150 mm:

GB/T 4171-2008: Atmospheric corrosion resisting structural steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness ** (J)
		C	P	S					
Q235NH	t ≤ 16	0.13	0.030	0.030	^	235	360 ~ 510	25	≥ 47J B) ≥ 34J (C) ≥ 34J (D) ≥ 27J (E)
	16 < t ≤ 40					225		25	
	40 < t ≤ 60					215		24	
	60 < t ≤ 100					215		23	
Q265GNH	t ≤ 3.5	0.12	0.070 ~ 0.120	0.020	^	265	≥410	27	
Q295NH	t ≤ 16	0.15	0.030	0.030	^	295	430 ~ 560	24	
	16 < t ≤ 40					285		24	
	40 < t ≤ 60					275		23	
	60 < t ≤ 100					255		22	
Q295GNH	t ≤ 16	0.12	0.070 ~ 0.120	0.020	^	295	430 ~ 560	24	
	16 < t ≤ 20					285		24	
Q310GNH	t ≤ 3.5	0.12	0.070 ~0.120	0.020	^	310	≥450	26	
Q355NH	t ≤ 16	0.16	0.030	0.030	^	355	490 ~ 630	22	
	16 < t ≤ 40					345		22	
	40 < t ≤ 60					335		21	
	60 < t ≤ 100					325		20	
Q355GNH	t ≤ 16	0.12	0.070 ~ 0.150	0.020	^	355	490 ~ 630	22	
	16 < t ≤ 20					345		22	
Q415NH	t ≤ 16	0.12	0.025	0.030	^	415	520 ~ 680	22	
	16 < t ≤ 40					405		22	
	40 < t ≤ 60					395		20	
Q460NH	t ≤ 16	0.12	0.025	0.030	^	460	570 ~ 730	20	
	16 < t ≤ 40					450		20	
	40 < t ≤ 60					440		19	
Q500NH	t ≤ 16	0.12	0.025	0.030	^	500	600 ~ 760	18	
	16 < t ≤ 40					490		16	
	40 < t ≤ 60					480		15	
Q550NH	t ≤ 16	0.16	0.025	0.030	^	550	620 ~ 780	16	
	16 < t ≤ 40					540		16	
	40 < t ≤ 60					530		15	

^ To be specified by the purchaser.

** If temperature is not specified, it depends on the quality level: 20°C for B class, 0°C for C class, -20°C for D class and -40°C for E class. Class A steel material has no requirement for toughness.

GB/T 19879-2015: Steel plate for building structure

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV ** (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness* (J)
		C	P	S					
Q235GJ	6 ≤ t ≤ 16	0.20 (B) 0.20 (C) 0.18 (D) 0.18 (E)	0.025 (B) 0.025 (C) 0.020 (D) 0.020 (E)	0.015 (B) 0.015 (C) 0.010 (D) 0.010 (E)	0.34 (AR, N)	≥ 235	400 ~ 510	23	≥ 47J (B~E)
	16 < t ≤ 50					235 ~ 345			
	50 < t ≤ 100				0.36 (AR, N)	225 ~ 355			
	100 < t ≤ 150				0.38 (AR, N)	215 ~ 325	380 ~ 510		
Q345GJ	6 ≤ t ≤ 16	0.20 (B) 0.20 (C) 0.18 (D) 0.18 (E)	0.025 (B) 0.025 (C) 0.020 (D) 0.020 (E)	0.015 (B) 0.015 (C) 0.010 (D) 0.010 (E)	0.42 (AR, N) 0.38 (M)	≥ 345	490 ~ 610	22	≥ 47J (B~E)
	16 < t ≤ 50					345 ~ 455			
	50 < t ≤ 100				0.44 (AR, N) 0.40 (M)	335 ~ 455			
	100 < t ≤ 150				0.46 (AR, N)	325 ~ 435	470 ~ 610		
	150 < t ≤ 200				0.47 (AR, N)	305 ~ 415	470 ~ 610		
Q390GJ	6 ≤ t ≤ 16	0.20 (B) 0.20 (C) 0.18 (D) 0.18 (E)	0.025 (B) 0.025 (C) 0.020 (D) 0.020 (E)	0.015 (B) 0.015 (C) 0.010 (D) 0.010 (E)	0.45 (AR, N) 0.40 (M)	≥ 390	510 ~ 660	20	≥ 47J (B~E)
	16 < t ≤ 50					390 ~ 510			
	50 < t ≤ 100				0.47 (AR, N) 0.43 (M)	380 ~ 500			
	100 < t ≤ 150				0.49 (AR, N)	370 ~ 490	490 ~ 640		
Q420GJ	6 ≤ t ≤ 16	0.20 (B) 0.20 (C) 0.18 (D) 0.18 (E)	0.025 (B) 0.025 (C) 0.020 (D) 0.020 (E)	0.015 (B) 0.015 (C) 0.010 (D) 0.010 (E)	0.48 (AR, N) 0.44 (Q) 0.40 (M)	≥ 420	530 ~ 680	20	≥ 47J (B~E)
	16 < t ≤ 50					420 ~ 550			
	50 < t ≤ 100				0.50 (AR, N) 0.47 (Q) ^ (M)	410 ~ 540			
	100 < t ≤ 150				0.52 (AR, N) 0.49 (Q)	400 ~ 530	510 ~ 660		
Q460GJ	6 ≤ t ≤ 16	0.20 (B) 0.20 (C) 0.18 (D) 0.18 (E)	0.025 (B) 0.025 (C) 0.020 (D) 0.020 (E)	0.015 (B) 0.015 (C) 0.010 (D) 0.010 (E)	0.52 (AR, N) 0.45 (Q) 0.42 (M)	≥ 460	570 ~ 720	18	≥ 47J (B~E)
	16 < t ≤ 50					460 ~ 600			
	50 < t ≤ 100				0.54 (AR, N) 0.48 (Q) ^ (M)	450 ~ 590			
	100 < t ≤ 150				0.56 (AR, N) 0.50 (Q)	440 ~ 580	550 ~ 720		
Q500GJ	12 ≤ t ≤ 20	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.020 (D) 0.020 (E)	0.015 (C) 0.010 (D) 0.010 (E)	0.52 (Q) 0.47 (M)	≥ 500	610 ~ 770	17	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	20 < t ≤ 40					500~ 640			
Q550GJ	12 ≤ t ≤ 20	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.020 (D) 0.020 (E)	0.015 (C) 0.010 (D) 0.010 (E)	0.54 (Q) 0.47 (M)	≥ 550	670 ~ 830	17	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	20 < t ≤ 40					550 ~ 690			
Q620GJ	12 ≤ t ≤ 20	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.020 (D) 0.020 (E)	0.015 (C) 0.010 (D) 0.010 (E)	0.58 (Q) 0.48 (M)	≥ 620	730 ~900	17	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	20 < t ≤ 40					620 ~ 770			
Q690GJ	12 ≤ t ≤ 20	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.020 (D) 0.020 (E)	0.015 (C) 0.010 (D) 0.010 (E)	0.60 (Q) 0.50 (M)	≥ 690	770 ~ 940	14	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	20 < t ≤ 40					690 ~ 860			

^ To be specified by the purchaser.

* If temperature is not specified, it depends on the quality level: 20°C for B class, 0°C for C class, -20°C for D class and -40°C for E class. Class A steel material has no requirement for toughness.

** If the delivery condition is not specified, the lowest limit is adopted. Delivery conditions of AR, N, Q and M should refer to Section 2.1.

GB/T 16270-2009: High strength structural steel plates in the quenched and tempered condition

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness (mm)</th><th colspan="3">Chemical composition (Class) (%)</th><th rowspan="2">Max. CEV ** (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness* (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td rowspan="3">Q460C
Q460D
Q460E
Q460F</td><td>t ≤ 50</td><td rowspan="3">0.20</td><td rowspan="3">0.025 (C)
0.025 (D)
0.020 (E)
0.020 (E)</td><td rowspan="3">0.015 (C)
0.015 (D)
0.010 (E)
0.010 (F)</td><td>0.47</td><td>460</td><td rowspan="2">550 ~ 720</td><td rowspan="3">17</td><td rowspan="3">≥ 47J (C,D)
≥ 34J (E,F)</td></tr>
<tr><td>50 < t ≤ 100</td><td>0.48</td><td>440</td></tr>
<tr><td>100 < t ≤ 150</td><td>0.50</td><td>400</td><td>500 ~ 670</td></tr>
<tr><td rowspan="3">Q500C
Q500D
Q500E
Q500F</td><td>t ≤ 50</td><td rowspan="3">0.20</td><td rowspan="3">0.025 (C)
0.025 (D)
0.020 (E)
0.020 (E)</td><td rowspan="3">0.015 (C)
0.015 (D)
0.010 (E)
0.010 (F)</td><td>0.47</td><td>500</td><td rowspan="2">590 ~ 770</td><td rowspan="3">17</td><td rowspan="3">≥ 47J (C,D)
≥ 47J (C,D)</td></tr>
<tr><td>50 < t ≤ 100</td><td>0.70</td><td>480</td></tr>
<tr><td>100 < t ≤ 150</td><td>0.70</td><td>440</td><td>540 ~ 720</td></tr>
<tr><td rowspan="3">Q550C
Q550D
Q550E
Q550F</td><td>t ≤ 50</td><td rowspan="3">0.20</td><td rowspan="3">0.025 (C)
0.025 (D)
0.020 (E)
0.020 (E)</td><td rowspan="3">0.015 (C)
0.015 (D)
0.010 (E)
0.010 (F)</td><td>0.65</td><td>550</td><td rowspan="2">640 ~ 820</td><td rowspan="3">16</td><td rowspan="3">≥ 34J (E,F)
≥ 47J (C,D)</td></tr>
<tr><td>50 < t ≤ 100</td><td>0.77</td><td>530</td></tr>
<tr><td>100 < t ≤ 150</td><td>0.83</td><td>490</td><td>590 ~ 770</td></tr>
<tr><td rowspan="3">Q620C
Q620D
Q620E
Q620F</td><td>t ≤ 50</td><td rowspan="3">0.20</td><td rowspan="3">0.025 (C)
0.025 (D)
0.020 (E)
0.020 (E)</td><td rowspan="3">0.015 (C)
0.015 (D)
0.010 (E)
0.010 (F)</td><td>0.65</td><td>620</td><td rowspan="2">700 ~ 890</td><td rowspan="3">15</td><td rowspan="3">≥ 47J (C,D)
≥ 47J (C,D)</td></tr>
<tr><td>50 < t ≤ 100</td><td>0.77</td><td>580</td></tr>
<tr><td>100 < t ≤ 150</td><td>0.83</td><td>560</td><td>650 ~ 830</td></tr>
<tr><td rowspan="3">Q690C
Q690D
Q690E
Q690F</td><td>t ≤ 50</td><td rowspan="3">0.20</td><td rowspan="3">0.025 (C)
0.025 (D)
0.020 (E)
0.020 (E)</td><td rowspan="3">0.015 (C)
0.015 (D)
0.010 (E)
0.010 (F)</td><td>0.65</td><td>690</td><td>770 ~ 940</td><td rowspan="3">14</td><td rowspan="3">≥ 34J (E,F)</td></tr>
<tr><td>50 < t ≤ 100</td><td>0.77</td><td>650</td><td>760 ~ 930</td></tr>
<tr><td>100 < t ≤ 150</td><td>0.83</td><td>630</td><td>710 ~ 900</td></tr>
</table>

^ To be specified by the purchaser.
* If temperature is not specified, it depends on the quality level: 0ºC for C class, -20ºC for D class, -40ºC for E class and -60ºC for F class.

with dimensional and/or mass tolerances in accordance with:-

GB/T 709

A.5.2 Acceptable Chinese structural steel: sections

GB/T 700-2006 Carbon structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s [d] (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q235	*Refer to GB/T 700 in Section A.5.1*								
Q275									

GB/T 1591-2018 High strength low alloy structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [e] (%)	Impact toughness [b] (J)
		C	P [g]	S [g]					
Q355	t ≤ 400	*Refer to GB/T 1591 in Section A.5.1*							
Q390	t ≤ 150								
Q420	t ≤ 16	0.20 (B) 0.20 (C)	0.035 (B) 0.030 (C)	0.035 (B) 0.030 (C)	0.45	420	520 ~ 680	20	≥ 34J (B) ≥ 34J (C)
	16 < t ≤ 40				0.45 [f]	410		20	
	40 < t ≤ 63				0.47	390		19	
	63 < t ≤ 80				0.48	370		19	
	80 < t ≤ 100					370		19	
	100 < t ≤ 150					350	500 ~ 650	19	
Q460	t ≤ 16	0.20 (C)	0.030 (C)	0.030 (C)	0.47	460	550 ~ 720	18	≥ 34J (C)
	16 < t ≤ 40				0.47 [f]	450		18	
	40 < t ≤ 63				0.49	430		17	
	63 < t ≤ 80				0.49	410		17	
	80 < t ≤ 100					410		17	
	100 < t ≤ 150					390	530 ~ 700	17	
Q355N	t ≤ 250	*Refer to GB/T 1591 in Section A.5.1*							
Q390N	t ≤ 250								
Q420N	t ≤ 250								
Q460N	t ≤ 250								
Q355M	t ≤ 150								
Q390M	t ≤ 150								
Q420M	t ≤ 150								
Q460M	t ≤ 150								
Q500M	t ≤ 100								
Q550M	t ≤ 100								
Q620M	t ≤ 80								
Q690M	t ≤ 80								

Note:
b. Longitudinal test pieces. If temperature is not specified, it depends on the quality level: 20°C for B class, 0°C for C class, -20°C for D class and -40°C for E class.
e. Longitudinal test pieces.
g. For section steels and steel bars the P and S content can be 0.005% higher.
f. When nominal thickness > 30 mm: C = 0.22% max, Max. CEV = 0.47% for Q420, Max. CEV = 0.49% for Q460.

GB/T 4171-2008: Atmospheric corrosion resisting structural steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness ** (J)
		C	P	S					
Q235NH	t ≤ 100	*Refer to GB/T 1591 in Section A.5.1*							≥ 47J B) ≥ 34J (C) ≥ 34J (D) ≥ 27J (E)
Q295NH	t ≤ 100	*Refer to GB/T 1591 in Section A.5.1*							
Q295GNH	t ≤ 16	*Refer to GB/T 1591 in Section A.5.1*							
	16 < t ≤ 40	0.12	0.070 ~ 0.120	0.020	^	285	430 ~ 560	24	
Q355NH	t ≤ 100	*Refer to GB/T 1591 in Section A.5.1*							
Q355GNH	t ≤ 16	*Refer to GB/T 1591 in Section A.5.1*							
	16 < t ≤ 40	0.12	0.070 ~ 0.150	0.020	^	345	490 ~ 630	22	

^ To be specified by the purchaser.
* The dimension in bracket is only for section steels.
** If temperature is not specified, it depends on the quality level: 20°C for B class, 0°C for C class, -20°C for D class and -40°C for E class. Class A steel material has no requirement for toughness.

with dimensional and/or mass tolerances in accordance with:-
GB/T 706 or GB/T 11263-2010

A.5.3 Acceptable Chinese structural steel: hollow sections

GB/T 700-2006 Carbon structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm²)	U_s [d] (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q235	*Refer to GB/T 700 in Section A.5.1*								
Q275									

GB/T 1591-2018 High strength low alloy structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q355	t ≤ 400	*Refer to GB/T 1591 in Section A.5.1*							
Q390	t ≤ 150								
Q355N	t ≤ 250								
Q390N	t ≤ 250								
Q420N	t ≤ 250								
Q460N	t ≤ 250								
Q355M	t ≤ 150								
Q390M	t ≤ 150								
Q420M	t ≤ 150								
Q460M	t ≤ 150								
Q500M	t ≤ 100								
Q550M	t ≤ 100								
Q620M	t ≤ 80								
Q690M	t ≤ 80								

GB/T 4171-2008: Atmospheric corrosion resisting structural steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness ** (J)
		C	P	S					
Q235NH	*Refer to GB/T 4171 in Section A.5.1*								
Q265GNH									
Q295NH									
Q295GNH									
Q310GNH									
Q355NH									
Q355GNH									
Q415NH									
Q460NH									
Q500NH									
Q550NH									

with dimensional and/or mass tolerances in accordance with:
GB/T 6728 or GB/T 6725

GB/T 8162-2018: Seamless steel tubes for structural purposes

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV ** (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness* (J)
		C	P	S					
Q345	t ≤ 16	0.20 (A) 0.20 (B) 0.20 (C) 0.18 (D) 0.18 (E)	0.030 (A) 0.030 (B) 0.030 (C) 0.030 (D) 0.025 (B)	0.030 (A) 0.030 (B) 0.030 (C) 0.025 (D) 0.020 (B)	0.45 (AR,N)	345	470 ~ 630	20 (A) 20 (B) 21 (C) 21 (D) 21 (E)	≥ 34J (B,C,D) ≥ 27J (E)
	16 < t ≤ 30				0.47 (AR,N)	325			
	30 < t				0.48 (AR,N)	295			
Q390	t ≤ 16	0.20 (A) 0.20 (B) 0.20(C) 0.20(D) 0.20(E)	0.030 (A) 0.030 (B) 0.030 (C) 0.030 (D) 0.025 (E)	0.030 (A) 0.030 (B) 0.030 (C) 0.025 (D) 0.020 (E)	0.46 (AR,N)	390	490 ~ 650	18 (A) 18 (B) 19 (C) 19 (D) 19 (E)	≥ 34J (B,C,D) ≥ 27J (E)
	16 < t ≤ 30				0.48 (AR,N)	370			
	30 < t				0.49 (AR,N)	350			
Q420	t ≤ 16	0.20 (A) 0.20 (B) 0.20 (C) 0.20 (D) 0.20 (E)	0.030 (A) 0.030 (B) 0.030 (C) 0.030 (D) 0.025 (E)	0.030 (A) 0.030 (B) 0.030 (C) 0.025 (D) 0.020 (E)	0.48 (AR,N)	420	520 ~ 680	18 (A) 18 (B) 19 (C) 19 (D) 19 (E)	≥ 34J (B,C,D) ≥ 27J (E)
	16 < t ≤ 30				0.50 (AR,N) 0.48 (Q)	400			
	30 < t				0.50 (AR,N) 0.48 (Q)	380			
Q460	t ≤ 16	0.20 (C) 0.20 (D) 0.20 (E)	0.030 (C) 0.030 (D) 0.025 (E)	0.030 (C) 0.025 (D) 0.020 (E)	0.53 (AR,N) 0.48 (Q)	460	550 ~ 720	17	≥ 34J (C,D) ≥ 27J (E)
	16 < t ≤ 30				0.55 (AR,N) 0.50 (Q)	440			
	30 < t				0.55 (AR,N) 0.50 (Q)	420			
Q500	t ≤ 16	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.025 (D) 0.020 (E)	0.020 (C) 0.015 (D) 0.010 (E)	0.48 (Q)	500	610 ~ 770	17	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	16 < t ≤ 30				0.50 (Q)	480			
	30 < t				0.50 (Q)	440			
Q550	t ≤ 16	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.025 (D) 0.020 (E)	0.020 (C) 0.015 (D) 0.010 (E)	0.48 (Q)	550	670 ~ 830	16	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	16 < t ≤ 30				0.50 (Q)	530			
	30 < t				0.50 (Q)	490			
Q620	t ≤ 16	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.025 (D) 0.020 (E)	0.020 (C) 0.015 (D) 0.010 (E)	0.50 (Q)	620	710 ~ 880	15	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	16 < t ≤ 30				0.52 (Q)	590			
	30 < t				0.52 (Q)	550			
Q690	t ≤ 16	0.18 (C) 0.18 (D) 0.18 (E)	0.025 (C) 0.025 (D) 0.020 (E)	0.020 (C) 0.015 (D) 0.010 (E)	0.50 (Q)	690	770 ~ 940	14	≥ 55J (C) ≥ 47J (D) ≥ 31J (E)
	16 < t ≤ 30				0.52 (Q)	660			
	30 < t				0.52 (Q)	620			

* If temperature is not specified, it depends on the quality level: 20°C for B class, 0°C for C class, -20°C for D class and -40°C for E class. Class A steel material has no requirement for toughness.

** If the delivery condition is not specified, the lowest limit is adopted. Delivery conditions of AR, N, Q and M should refer to Section 2.1.

with dimensional and/or mass tolerances in accordance with:
GB/T 8162 or GB/T 17395

A.5.4 Acceptable Chinese structural steel: sheet piles

GB/T 20933-2014: Hot rolled sheet pile

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q295P	8.8 < t ≤ 27.6	0.16	0.035	0.035	0.40	295	390 ~ 570	23	^
Q345P	8.8 < t ≤ 27.6	0.20	0.035	0.035	0.42	345	480~630	22	^
Q390P	8.8 < t ≤ 27.6	0.20	0.035	0.035	0.44	390	490 ~ 650	20	^
Q420P	8.8 < t ≤ 27.6	0.20	0.035	0.035	0.46	420	520 ~ 680	19	^
Q460P	8.8 < t ≤ 27.6	0.20	0.030	0.030	0.46	460	550~720	17	^

^ To be specified by the purchaser.

with dimensional and/or mass tolerances in accordance with:
GB/T 20933

A.5.5 Acceptable Chinese structural steel: solid bars

GB/T 700-2006 Carbon structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm²)	U_s [d] (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q235	*Refer to GB/T 700 in Section A.5.1*								
Q275									

GB/T 1591-2018 High strength low alloy structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L [e] (%)	Impact toughness [b] (J)
		C	P [g]	S [g]					
Q355	t ≤ 400	*Refer to GB/T 1591 in Section A.5.2*							
Q390	t ≤ 150								
Q420	t ≤ 150								
Q460	t ≤ 150								
Q355N	t ≤ 250								
Q390N	t ≤ 250								
Q420N	t ≤ 250								
Q460N	t ≤ 250								
Q355M	t ≤ 150								
Q390M	t ≤ 150								
Q420M	t ≤ 150								
Q460M	t ≤ 150								
Q500M	t ≤ 100								
Q550M	t ≤ 100								
Q620M	t ≤ 80								
Q690M	t ≤ 80								

with dimensional and/or mass tolerances in accordance with:
GB/T 702

A.5.6 Acceptable Chinese structural steel: strips for cold formed open sections

GB/T 700-2006 Carbon structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s [d] (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q235	*Refer to GB/T 700 in Section A.5.1*								
Q275									

GB/T 1591-2018 High strength low alloy structural steels

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L [e] (%)	Impact toughness [b] (J)
		C	P [g]	S [g]					
Q355	t ≤ 400	*Refer to GB/T 1591 in Section A.5.1*							
Q390	t ≤ 150								
Q355N	t ≤ 250								
Q390N	t ≤ 250								
Q420N	t ≤ 250								
Q460N	t ≤ 250								
Q355M	t ≤ 150								
Q390M	t ≤ 150								
Q420M	t ≤ 150								
Q460M	t ≤ 150								
Q500M	t ≤ 100								
Q550M	t ≤ 100								
Q620M	t ≤ 80								
Q690M	t ≤ 80								

GB/T 4171-2008: Atmospheric corrosion resisting structural steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness ** (J)
		C	P	S					
Q235NH	t ≤ 100	*Refer to GB/T 4171 in Section A.5.1*							
Q265GNH	t ≤ 3.5								
Q295NH	t ≤ 100								
Q295GNH	t ≤ 20								
Q310GNH	t ≤ 3.5								
Q355NH	t ≤ 100								
Q355GNH	t ≤ 20								
Q415NH	t ≤ 60								
Q460NH	t ≤ 60								
Q500NH	t ≤ 60								
Q550NH	t ≤ 60								

GB/T 19879-2015: Steel plate for building structure

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q235GJ	6 ≤ t ≤ 150	*Refer to GB/T 19879 in Section A.5.1*							
Q345GJ	6 ≤ t ≤ 200								
Q390GJ	6 ≤ t ≤ 150								
Q420GJ	6 ≤ t ≤ 150								
Q460GJ	6 ≤ t ≤ 150								
Q500GJ	12 ≤ t ≤ 40								
Q550GJ	12 ≤ t ≤ 40								
Q620GJ	12 ≤ t ≤ 40								
Q690GJ	12 ≤ t ≤ 40								

GB/T 16270-2009: High strength structural steel plates in the quenched and tempered condition

Grade	Thickness (mm)	Chemical composition (Class) (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Q460C Q460D Q460E Q460F	t ≤ 150	*Refer to GB/T 16270 in Section A.5.1*							
Q500C Q500D Q500E Q500F	t ≤ 150								
Q550C Q550D Q550E Q550F	t ≤ 150								
Q620C Q620D Q620E Q620F	t ≤ 150								
Q690C Q690D Q690E Q690F	t ≤ 150								

^ To be specified by the purchaser.

* If temperature is not specified, it depends on the quality level: 0°C for C class, -20°C for D class, -40°C for E class and -60°C for F class.

with dimensional and/or mass tolerances in accordance with:
GB/T 709

A.5.7 Acceptable Chinese strips for cold-formed profiled sheetings

GB/T 2518-2019: Continuously hot-dip zinc-coated steel sheet and strip

Grade*	Thickness (mm)	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S				
S220GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6	0.20	0.10	0.045	220	300	20	^
S250GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				250	330	19	^
S280GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				280	360	18	^
S300GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				300	370	18	^
S320GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				320	390	17	^
S350GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				350	420	16	^
S390GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				390	460	16	^
S420GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				420	480	15	^
S450GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				450	510	14	^
S550GD+Z (+ZF, +ZA, +AZ)	0.2 ≤ t ≤ 6				550	560	^	^

^ To be specified by the purchaser.
* Pure zinc coating is expressed in "Z"; zinc-iron alloy coating is expressed in "ZF"; zinc- aluminum alloy coating is expressed in "ZA"; aluminum-zinc alloy coating is expressed in "AZ".

with dimensional and/or mass tolerances in accordance with:
GB/T 2518 and GB/T 25052

A.5.8 Acceptable Chinese stud shear connectors

GB/T 10433-2002: Cheese head studs for arc stud welding

Grade	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
	C	P	S				
ML15	0.18	0.035	0.035	320	400	14	^
ML15Al	0.18	0.035	0.035	320	400	14	^

^ To be specified by the purchaser.

A.5.9 Acceptable Chinese non-preloaded bolting assemblies

GB/T 3098.1-2010: Mechanical properties of fasteners – Bolts, screws and studs

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">S_p^f (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>4.6</td><td>3 ≤ D ≤ 39</td><td>≤ 0.55</td><td>0.050</td><td>0.060</td><td>240</td><td>400</td><td>22</td><td>^</td></tr>
<tr><td>4.8</td><td>3 ≤ D ≤ 39</td><td>≤ 0.55</td><td>0.050</td><td>0.060</td><td>340</td><td>420</td><td>24</td><td>^</td></tr>
<tr><td>5.6</td><td>3 ≤ D ≤ 39</td><td>0.13 ~ 0.55</td><td>0.050</td><td>0.060</td><td>300</td><td>500</td><td>20</td><td>27J @ -20ºC</td></tr>
<tr><td>5.8</td><td>3 ≤ D ≤ 39</td><td>≤ 0.55</td><td>0.050</td><td>0.060</td><td>420</td><td>520</td><td>22</td><td>^</td></tr>
<tr><td>6.8</td><td>3 ≤ D ≤ 39</td><td>0.15 ~ 0.55</td><td>0.050</td><td>0.060</td><td>480</td><td>600</td><td>20</td><td>^</td></tr>
<tr><td rowspan="2">8.8</td><td>3 ≤ D ≤ 16</td><td rowspan="2">0.15 ~ 0.55</td><td rowspan="2">0.025</td><td rowspan="2">0.025</td><td>640</td><td>800</td><td rowspan="2">12</td><td>27J @ -20ºC</td></tr>
<tr><td>16 < D ≤ 39</td><td>660</td><td>830</td><td></td></tr>
<tr><td>9.8</td><td>3 ≤ D ≤ 16</td><td>0.15 ~ 0.55</td><td>0.025</td><td>0.025</td><td>720</td><td>900</td><td>10</td><td>27 J @ -20ºC</td></tr>
<tr><td>10.9</td><td>3 ≤ D ≤ 39</td><td>0.20 ~ 0.55</td><td>0.025</td><td>0.025</td><td>940</td><td>1040</td><td>9</td><td>27 J @ -20ºC</td></tr>
<tr><td>12.9</td><td>3 ≤ D ≤ 39</td><td>0.28 ~ 0.50</td><td>0.025</td><td>0.025</td><td>1100</td><td>1220</td><td>8</td><td>^</td></tr>
</table>

^ To be specified by the purchaser.

GB/T 3098.2-2015: Mechanical properties of fasteners – Nuts

1. Coarse thread

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2" colspan="2">Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">S_p^f (N/mm^2)</th><th rowspan="2">ε_L (%)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>04</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.060</td><td>0.150</td><td>380</td><td>^</td></tr>
<tr><td>05</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>500</td><td>^</td></tr>
<tr><td>5</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.060</td><td>0.150</td><td>520 ~ 630</td><td>^</td></tr>
<tr><td>6</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.060</td><td>0.150</td><td>600 ~ 720</td><td>^</td></tr>
<tr><td rowspan="3">8</td><td>High nut</td><td>5 ≤ D ≤ 39</td><td>0.58</td><td>0.060</td><td>0.150</td><td rowspan="3">800 ~ 920</td><td></td></tr>
<tr><td rowspan="2">Regular nut</td><td>5 ≤ D ≤ 16</td><td>0.58</td><td>0.060</td><td>0.150</td><td>^</td></tr>
<tr><td>16 < D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>^</td></tr>
<tr><td>10</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>1040 ~ 1060</td><td>^</td></tr>
<tr><td>12</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>1140 ~ 1200</td><td>^</td></tr>
</table>

2. Fine pitch thread

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2" colspan="2">Diameter (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">S_p^f (N/mm^2)</th><th rowspan="2">ε_L (%)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td>04</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.060</td><td>0.150</td><td>380</td><td>^</td></tr>
<tr><td>05</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>500</td><td>^</td></tr>
<tr><td>5</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.060</td><td>0.150</td><td>690 ~ 720</td><td>^</td></tr>
<tr><td rowspan="2">6</td><td colspan="2">5 ≤ D ≤ 16</td><td>0.58</td><td>0.060</td><td>0.150</td><td>770 ~ 780</td><td>^</td></tr>
<tr><td colspan="2">16 < D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>870 ~ 930</td><td></td></tr>
<tr><td rowspan="2">8</td><td>High nut</td><td rowspan="2">16 < D ≤ 39</td><td>0.58</td><td>0.060</td><td>0.150</td><td rowspan="2">890 ~ 1090</td><td>^</td></tr>
<tr><td>Regular nut</td><td>0.58</td><td>0.048</td><td>0.058</td><td>^</td></tr>
<tr><td>10</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>1100~ 1080</td><td>^</td></tr>
<tr><td>12</td><td colspan="2">5 ≤ D ≤ 39</td><td>0.58</td><td>0.048</td><td>0.058</td><td>1200</td><td>^</td></tr>
</table>

^ To be specified by the purchaser.

A.5.10 Acceptable Chinese preloaded bolting assemblies

*Refer to **Section A.5.9***

A.5.11 Acceptable Chinese welding consumables

GB/T 5117-2012: Covered electrodes for manual metal arc welding of non-alloy and fine grain steels

Grade	Chemical composition (%)			Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)
	C	P	S			
E4303	0.20	0.040	0.035	330	430	20
E4310	0.20	0.040	0.035	330	430	20
E4311	0.20	0.040	0.035	330	430	20
E4312	0.20	0.040	0.035	330	430	16
E4313	0.20	0.040	0.035	330	430	16
E4315	0.20	0.040	0.035	330	430	16
E4316	0.20	0.040	0.035	330	430	20
E4318	0.03	0.025	0.015	330	430	20
E4319	0.20	0.040	0.035	330	430	20
E4320	0.20	0.040	0.035	330	430	20
E4324	0.20	0.040	0.035	330	430	16
E4327	0.20	0.040	0.035	330	430	20
E4328	0.20	0.040	0.035	330	430	20
E4340	^	0.040	0.035	330	430	20
E5003	0.15	0.040	0.035	400	490	20
E5010	0.20	0.035	0.035	400	490 ~ 650	20
E5011	0.20	0.035	0.035	400	490 ~ 650	20
E5012	0.20	0.035	0.035	400	490	16
E5013	0.20	0.035	0.035	400	490	16
E5014	0.15	0.035	0.035	400	490	16
E5015	0.15	0.035	0.035	400	490	20
E5016	0.15	0.035	0.035	400	490	20
E5016-1	0.15	0.035	0.035	400	490	20
E5018	0.15	0.035	0.035	400	490	20
E5018-1	0.15	0.035	0.035	400	490	20
E5019	0.15	0.035	0.035	400	490	20
E5024	0.15	0.035	0.035	400	490	16
E5024-1	0.15	0.035	0.035	400	490	20
E5027	0.15	0.035	0.035	400	490	20
E5028	0.15	0.035	0.035	400	490	20
E5048	0.15	0.035	0.035	400	490	20
E5716	0.12	0.030	0.030	490	570	16
E5728	0.12	0.030	0.030	490	570	16

(To be continued)

(Continued)

Grade	Chemical composition (%)			Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)
	C	P	S			
E5010-p1	0.20	0.030	0.030	420	490	20
E5510-P1	0.20	0.030	0.030	460	550	17
E5518-P2	0.12	0.030	0.030	460	550	17
E5545-P2	0.12	0.030	0.030	460	550	17
E5003-1M3	0.12	0.030	0.030	400	490	20
E5010-1M3	0.12	0.030	0.030	420	490	20
E5011-1M3	0.12	0.030	0.030	400	490	20
E5015-1M3	0.12	0.030	0.030	400	490	20
E5016-1M3	0.12	0.030	0.030	400	490	20
E5018-1M3	0.12	0.030	0.030	400	490	20
E5019-1M3	0.12	0.030	0.030	400	490	20
E5020-1M3	0.12	0.030	0.030	400	490	20
E5027-1M3	0.12	0.030	0.030	400	490	20
E5518-3M2	0.12	0.030	0.030	460	550	17
E5515-3M3	0.12	0.030	0.030	460	550	17
E5516-3M3	0.12	0.030	0.030	460	550	17
E5518-3M3	0.12	0.030	0.030	460	550	17
E5015-N1	0.12	0.030	0.030	390	490	20
E5016-N1	0.12	0.030	0.030	390	490	20
E5028-N1	0.12	0.030	0.030	390	490	20
E5515-N1	0.12	0.030	0.030	460	550	17
E5516-N1	0.12	0.030	0.030	460	550	17
E5528-N1	0.12	0.030	0.030	460	550	17
E5015-N2	0.08	0.030	0.030	390	490	20
E5016-N2	0.08	0.030	0.030	390	490	20
E5018-N2	0.08	0.030	0.030	390	490	20
E5515-N2	0.12	0.030	0.030	470 ~ 550	550	20
E5516-N2	0.12	0.030	0.030	470 ~ 550	550	20
E5518-N2	0.12	0.030	0.030	470 ~ 550	550	20
E5015-N3	0.10	0.030	0.030	390	490	20
E5016-N3	0.10	0.030	0.030	390	490	20
E5515-N3	0.10	0.030	0.030	460	550	17
E5516-N3	0.10	0.030	0.030	460	550	17
E5516-3N3	0.10	0.030	0.030	460	550	17
E5518-N3	0.10	0.030	0.030	460	550	17
E5015-N5	0.05	0.030	0.030	390	490	20
E5016-N5	0.05	0.030	0.030	390	490	20
E5018-N5	0.05	0.030	0.030	390	490	20
E5028-N5	0.10	0.025	0.020	390	490	20
E5515-N5	0.12	0.030	0.030	460	550	17
E5516-N5	0.12	0.030	0.030	460	550	17
E5518-N5	0.12	0.030	0.030	460	550	17

(To be continued)

(Continued)

Grade	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
	C	P	S			
E5015-N7	0.05	0.030	0.030	390	490	20
E5016-N7	0.05	0.030	0.030	390	490	20
E5018-N7	0.05	0.030	0.030	390	490	20
E5515-N7	0.12	0.030	0.030	460	550	17
E5516-N7	0.12	0.030	0.030	460	550	17
E5518-N7	0.12	0.030	0.030	460	550	17
E5515-N13	0.06	0.025	0.020	460	550	17
E5516-N13	0.06	0.025	0.020	460	550	17
E5518-N2M3	0.10	0.020	0.020	460	550	17
E5003-NC	0.12	0.030	0.030	390	490	20
E5016-NC	0.12	0.030	0.030	390	490	20
E5028-NC	0.12	0.030	0.030	390	490	20
E5716-NC	0.12	0.030	0.030	490	570	16
E5728-NC	0.12	0.030	0.030	490	570	16
E5003-CC	0.12	0.030	0.030	390	490	20
E5016-CC	0.12	0.030	0.030	390	490	20
E5028-CC	0.12	0.030	0.030	390	490	20
E5716-CC	0.12	0.030	0.030	490	570	16
E5728-CC	0.12	0.030	0.030	490	570	16
E5003-NCC	0.12	0.030	0.030	390	490	20
E5016-NCC	0.12	0.030	0.030	390	490	20
E5028-NCC	0.12	0.030	0.030	390	490	20
E5716-NCC	0.12	0.030	0.030	490	570	16
E5728-NCC	0.12	0.030	0.030	490	570	16
E5003-NCC1	0.12	0.030	0.030	390	490	20
E5016-NCC1	0.12	0.030	0.030	390	490	20
E5028-NCC1	0.12	0.030	0.030	390	490	20
E5516-NCC1	0.12	0.030	0.030	460	550	17
E5518-NCC1	0.12	0.030	0.030	460	550	17
E5716-NCC1	0.12	0.030	0.030	490	570	16
E5728-NCC1	0.12	0.030	0.030	490	570	16
E5016-NCC2	0.12	0.025	0.025	420	490	20
E5018-NCC2	0.12	0.025	0.025	420	490	20
E50XX-G*	^	^	^	400	490	20
E55XX-G*	^	^	^	460	550	17
E57X-G*	^	^	^	490	570	16

^ To be specified by the purchaser.
* "XX" denotes the type of electrode's cover.

GB/T 5118-2012: Covered electrodes for manual metal arc welding of creep-resisting steels

Grade*	Chemical composition (%)			Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)
	C	P	S			
E50XX-1M3	0.12	0.030	0.030	390	490	22
E50YY-1M3	0.12	0.030	0.030	390	490	20
E55XX-CM	0.05 ~ 0.12	0.030	0.030	460	550	17
E5540-CM	0.05 ~ 0.12	0.030	0.030	460	550	14
E5503-CM	0.05 ~ 0.12	0.030	0.030	460	550	14
E55XX-C1M	0.07 ~ 0.15	0.030	0.030	460	550	17
E55XX-1CM	0.05 ~ 012	0.030	0.030	460	550	17
E5513-1CM	0.05 ~ 012	0.030	0.030	460	550	14
E52XX-1CML	0.05	0.030	0.030	390	520	17
E5540-1CMV	0.05 ~ 0.12	0.030	0.030	460	550	14
E5515-1CMV	0.05 ~ 0.12	0.030	0.030	460	550	15
E5515-1CMVNb	0.05 ~ 0.12	0.030	0.030	460	550	15
E5515-1CMWV	0.05 ~ 0.12	0.030	0.030	460	550	15
E62XX-2C1M	0.05 ~ 0.12	0.030	0.030	530	620	15
E6240-2C1M	0.05 ~ 0.12	0.030	0.030	530	620	12
E6213-2C1M	0.05 ~ 0.12	0.030	0.030	530	620	12
E55XX-2C1ML	0.05	0.030	0.030	460	550	15
E55XX-2CML	0.05	0.030	0.030	460	550	15
E5540-2CMWVB	0.05 ~ 0.12	0.030	0.030	460	550	14
E5515-2CMWVB	0.05 ~ 0.12	0.030	0.030	460	550	15
E5515-2CMVNb	0.05 ~ 0.12	0.030	0.030	460	550	15
E62XX-2C1MV	0.05 ~ 0.15	0.030	0.030	530	620	15
E62XX-3C1MV	0.05 ~ 0.15	0.030	0.030	530	620	15
E55XX-5CM	0.05 ~ 0.10	0.030	0.030	460	550	17
E55XX-5CML	0.05	0.030	0.030	460	550	17
E55XX-5CMV	0.12	0.030	0.030	460	550	14
E55XX-7CM	0.05 ~ 0.10	0.030	0.030	460	550	17
E55XX-7CML	0.05	0.030	0.030	460	550	17
E62XX-9C1M	0.05 ~ 0.10	0.030	0.030	530	620	15
E62XX-9C1ML	0.05	0.030	0.030	530	620	15
E62XX-9C1MV	0.08 ~ 0.13	0.010	0.01	530	620	15
E62XX-9C1MV1	0.03 ~ 0.12	0.025	0.025	530	620	15

^ To be specified by the purchaser.

* "XX" denotes Type 15, 16 or 18 of electrode's cover, while "YY" denotes Type 10, 11, 19, 20 or 27.

A.6 Acceptable Russian steel materials

A.6.1 Acceptable Russian structural steel: plates

GOST 27772-2015 - Rolled products for steel structural elements. General specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact Toughness (J)
		C	P	S					
C245	4 ≤ t ≤ 30	0.22	0.040	0.025	^	235	370	24	≥34J @ 0℃
C255	4 ≤ t ≤ 10	0.17	0.035	0.025	^	245	380	25	≥34J @ 0℃ ≥34J @ -20℃
	10 < t ≤ 20					245	370	25	
	20 ≤ t ≤ 40					235	370	25	
C345	4≤ t ≤ 10	0.15	0.030	0.025	0.45	345	490	21	≥34J @ -20℃ ≥34J @ -40℃
	10 < t ≤ 20					325	470	21	
	20 < t ≤ 40					305	460	21	
	40 < t ≤ 60					285	450	21	
	60 < t ≤ 80					275	440	21	
	80 < t ≤ 160					265	430	21	
C355	8 ≤ t ≤ 16	0.14	0.025	0.025	0.45	355	470	21	≥34J @ -20℃ ≥34J @ -40℃
	16 < t ≤ 40					345	470	21	
	40 < t ≤ 60					335	470	21	
	60 < t ≤ 80					325	460	21	
	80 < t ≤ 100					315	460	21	
	100 < t ≤ 160					295	460	21	
C355-1	8 ≤ t ≤ 16	0.15	0.017	0.015	0.45	355	470	21	≥34J @ -20℃ ≥34J @ -40℃
	16 < t ≤ 40					345	470	21	
	40 < t ≤ 50					335	470	21	
C355K	8 ≤ t ≤ 16	0.15	0.020	0.015	0.45	355	470	21	≥34J @ -20℃ ≥34J @ -40℃
	16 < t ≤ 40					345	470	21	
	40 < t ≤ 50					335	470	21	
C355П	8 ≤ t ≤ 16	0.10	0.020	0.015	0.45	355	470	21	≥34J @ -20℃
	16 < t ≤ 40					345	470	21	≥34J @ -40℃
C390 (C390-1)	8 ≤ t ≤ 50	0.12	0.017	0.010	0.46	390	520	20	≥34J @ -40℃ ≥34J @ -60℃
C440	8 ≤ t ≤ 50	0.12	0.017	0.010	0.46	440	540	20	≥66J @ -40℃ ≥66J @ -60℃
C550	8 ≤ t ≤ 50	0.10	0.015	0.007	0.47	540	640	17	≥66J @ -40℃ ≥66J @ -60℃
C590	8 ≤ t ≤ 40	0.10	0.015	0.004	0.51	590	685	14	≥66J @ -40℃ ≥66J @ -60℃

^ To be specified by the purchaser.

Note: letter “C” - “Structure Steel”; figure “1” – another option of chemical composition; letter “K” - the steel of improved corrosion resistance; letter “П” - the steel of improved fire resistance.

GOST 14637-89 - Rolled plate from carbon steel of general quality. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact Toughness (J)
		C	P**	S**					
Ст3кп	5 ≤ t ≤ 20	0.14~0.22	0.040	0.050	^	235	360~460	27	^
	20 < t ≤ 40					225		26	
	40 < t ≤ 100					215		24	
	100 < t ≤ 160					195		24	
Ст3пс, Ст3сп	5 ≤ t ≤ 20	0.14~0.22	0.040	0.050	^	245	370~480	26	≥34J @ 20℃ ≥30J @ 0℃
	20 < t ≤ 40					235		25	^
	40 < t ≤ 100					225		23	
	100 < t ≤ 160					205		23	
Ст3Гпс	5 ≤ t ≤20	0.14~0.22	0.040	0.050	^	245	370~490	26	≥34J @ 20℃ ≥30J @ 0℃
	20 < t ≤ 40					235		25	^
	40 < t ≤ 100					225		23	
	100 < t ≤ 160					205		23	
Ст3Гсп	5 ≤ t ≤20	0.14~0.20	0.040	0.050	^	255	390~570	23	≥34J @ 20℃ ≥30J @ 0℃
	20 < t ≤ 40					245		24	^
Ст4пс, Ст4сп	5 ≤ t ≤ 20	0.18~0.27*	0.040	0.050	^	265	410~530	24	^
	20 < t ≤ 40					255		23	
	40 < t ≤ 100					245		21	
	100 < t ≤ 160					235		21	
Ст5Гпс	5 ≤ t ≤20	0.22~0.30*	0.040	0.050	^	285	450~590	20	^
	20 < t ≤ 40					275		19	
	40 < t ≤ 100					265		17	
	100 < t ≤ 160					255		17	

^ To be specified by the purchaser.

* The mass fraction of carbon for welded structures must not exceed 0.22%.

** At the request of the customer, the mass fraction shall not exceed 0.040% for sulfur and 0.030% for phosphorus in rolled steel of categories 1 to 5, and each of these elements shall not exceed 0.025% in rolled steel of category 6.

Note: letter "Ст" - "Steel"; letter "Г" - the mass fraction of manganese in steel is not less than 0.80 %; letters "кп", "пс", "сп" - the deoxidation degree of steel is rimmed, semiskilled, and killed respectively.

GOST 19281-2014 - High strength rolled steel. General specification

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact Toughness (J)
		C	P	S					
265	t ≤ 160	0.14	0.030	0.035	0.43	265	430	21	≥34J @ 0℃ and ≥29J @-20℃ for t ≤ 20mm
295	t ≤ 100	0.14	0.030	0.035	0.43	295	430	21	≥34J @ 0℃, ≥29J @-20℃
315	t ≤ 60	0.18	0.030	0.035	0.43	315	450	21	≥34J @ 0℃, ≥29J @-20℃
325	t ≤ 60	0.22	0.030	0.035	0.43	325	450	21	≥34J @ 0℃, ≥29J @-20℃
345	t ≤ 50	0.22	0.030	0.035	0.46	345	490	21	≥34J @ -20℃ for t≤12mm, ≥39J @ 0℃ & -20℃ for 12mm<t≤50mm

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact Toughness (J)
		C	P	S					
355	t ≤ 50	0.22	0.030	0.035	0.46	355	490	20	≥34J @ 0℃, ≥29J @-20℃
375	t ≤ 50	0.22	0.030	0.035	0.46	375	510	20	≥29J @-20℃
390	t ≤ 50	0.22	0.030	0.035	0.48	390	510	19	≥29J @ -20℃ for t≤10mm, ≥39J @ 0℃ & ≥29J @ -20℃ for 10mm<t≤15mm, ≥39J @ 0℃ & -20℃ for 15mm<t≤50mm
440	t ≤50	0.22	0.030	0.035	0.51	440	590	19	≥29J @-20℃
460	t ≤ 50	0.12	0.030	0.035	0.47	460	540~720	17	≥29J @-20℃

GOST 11269-76: Alloyed universal structural high-grade rolled steel plates and wide strips for special purposes. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
25ХГСА	4 < t ≤ 60	0.22-0.28	0.0250	0.0250	^	^	490-690	21	^
12Х2НМФА	4 < t ≤ 60	0.09-0.16	0.0250	0.0250	^	^	490-740	15	^
12Х2НВФА									
12Х2НМ1ФА									
12Х2НВФМА									
19Х2НМФА	4 < t ≤ 60	0.16-0.23	0.0250	0.0250	^	^	490-740	18	^
19Х2НВФА									
21Х2НМФА	4 < t ≤ 60	0.19-0.23	0.0250	0.0250	^	^	490-740	15	^
21Х2НВФА									
23Х2НМФА	4 < t ≤ 60	0.19-0.26	0.0250	0.0250	^	^	490-780	17	^
23Х2НВФА									

^ To be specified by the purchaser.

* Steels in the table are in normalized condition.

Note: the first two figures - the average mass fraction of carbon (w(C)% × 100); letters "Х", "Г", "С", "М", "Ф", "В", "Н" – alloy element of Chromium, Manganese, Silicon, Molybdenum, Vanadium, Tungsten, Nickel; the figure after the letter - approximate mass fraction of allying elements in whole units, and its absence means the mass fraction of alloy element is up to 1.5%; letter "А" - high-quality steel.

GOST 1577-93 - Rolled sheets and wide strips of structural quality steel. Specifications

1. In normalized condition

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)		Impact toughness (J)
		C	P	S				along rolled direction	across rolled direction	
20	4 ≤ t ≤ 100	0.17~0.24	0.030	0.035	^	230	400~550	27	25	^
	100 < t ≤ 160					210	380~520	25	23	^

(To be continued)

(Continued)

2. In heat-treated condition

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
20	4 ≤ t ≤ 16	0.17~0.24	0.030	0.035	^	350	550 - 700	20	≥50J @ 20℃
	16 < t ≤ 40					300	500 - 650	22	

^ To be specified by the purchaser.

Note: the two figures - the average mass fraction of carbon (w(C)% × 100).

with dimensional and/or mass tolerances in accordance with:

GOST 19903-2015

A.6.2 Acceptable Russian structural steel: sections

GOST 27772-2015 - Rolled products for steel structural elements. General specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
C245	4 ≤ t ≤ 20	0.22	0.040	0.025	^	245	370	25	≥34J @ 0℃
	20 < t ≤ 40					235	370	24	
C255	4 ≤ t ≤ 10	0.17	0.035	0.025	^	255	380	25	≥34J @ -20℃
	10 < t ≤ 20					245	370	25	
	20 < t ≤ 40					235	370	24	
C345	4 ≤ t ≤ 10	0.15	0.030	0.025	0.45	345	480	21	^
	10 < t ≤ 20					325	470	21	
	20 < t ≤ 40					305	460	21	
C355	8 ≤ t ≤ 16	0.14	0.025	0.025	0.45	355	470	21	≥34J @ -20℃
	16 < t ≤ 40					345	470	21	
C355-1	8 ≤ t ≤ 16	0.15	0.02	0.02	0.45	355	480	21	≥34J @ -20℃
	16 < t ≤ 40					345	480	21	
C390	8 ≤ t ≤ 10	0.12	0.017	0.010	0.46	390	520	20	≥34J @ -20℃ ≥34J @ -40℃
	10 < t ≤ 20					380	500	20	
	20 < t ≤ 40					370	490	20	

^ To be specified by the purchaser.
Note: letter "C" - "Structure Steel"; figure "1" - the option of chemical composition; "K" - the steel of improved corrosion resistance.

OST 19281-2014 - High strength rolled steel. General specification

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact Toughness (J)
		C	P	S					
265	t ≤ 100	0.14	0.030	0.035	0.43	265	430	21	^
295	t ≤ 100	0.14	0.030	0.035	0.43	295	430	21	^
315	t ≤ 140	0.18	0.030	0.035	0.43	315	440	21	^
325	t ≤ 60	0.22	0.030	0.035	0.43	325	450	21	≥34J @ 0℃ & -20℃ for t ≤ 20mm
345	t ≤ 20	0.22	0.030	0.035	0.46	345	480	21	≥39J @ 0℃ & -20℃ for t ≤10mm
	20 < t ≤ 140								
355	t ≤ 140	0.22	0.030	0.035	0.46	355	480	21	^
375	t ≤ 20	0.22	0.030	0.035	0.46	375	510	21	^
	20 < t ≤ 50								
390	t ≤ 20	0.22	0.030	0.035	0.48	390	530	19	^
	20 < t ≤ 50								
440	t ≤ 16	0.22	0.030	0.035	0.51	440	590	19	^

^ To be specified by the purchaser.

GOST 535-2005 - Common quality carbon steel bar and shaped sections. General specifications

Grade	Thickness (mm)	Chemical composition (%) C	P	S	Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	□ (%)	Impact toughness (J)
Ст3кп	t ≤ 10	0.14~0.22	0.040	0.050	0.45	235	360~460	27	^
	10 < t ≤ 20					235		27	
	20 < t ≤ 40					225		26	
	40 < t ≤ 100					215		24	
Ст3пс	t ≤ 10	0.14~0.22	0.040	0.050	0.45	245	370~480	26	≥34J @ +20℃ for t≤26mm
	10 < t ≤ 20					245		26	
	20 < t ≤ 40					235		25	
	40 < t ≤ 100					225		23	
Ст3сп	t ≤ 10	0.14~0.22	0.040	0.050	0.45	255	380~490	26	≥34J @ +20℃ for t≤26mm
	10 < t ≤ 20					245	370~480	26	
	20 < t ≤ 40					235		25	
	40 < t ≤ 100					225		23	
Ст3Гпс	t ≤ 10	0.14~0.22	0.040	0.050	0.45	^	370~490	26	≥34J @ +20℃ for t≤26mm
	10 < t ≤ 20					245		26	
	20 < t ≤ 40					235		25	
	40 < t ≤ 100					225		23	
Ст3Гсп	t ≤ 20	0.14~0.20	0.040	0.050	0.45	^	390~570	^	≥34J @ +20℃ for t≤26mm
	20 < t ≤ 40					245		24	
Ст4кп	t ≤ 10	0.18~0.27	0.040	0.050	0.45	255	400~510	25	^
	10 < t ≤ 20					255		25	
	20 < t ≤ 40					245		24	
	40 < t ≤ 100					235		22	
Ст4пс, Ст4сп	t ≤ 10	0.18~0.27*	0.040	0.050	0.45	265	410~530	24	^
	10 < t ≤ 20					265		24	
	20 < t ≤ 40					255		23	
	40 < t ≤ 100					245		21	
Ст5Гпс	t ≤ 10	0.22~0.30*	0.040	0.050	0.45	^	450~590	20	^
	10 < t ≤ 20					285		20	
	20 < t ≤ 40					275		19	
	40 < t ≤ 100					265		17	

^ To be specified by the purchaser.
* The mass fraction of carbon for welded structures must not exceed 0.22%.
Note: letter “Ст” - “Steel”; letter 'Г” - the mass fraction of manganese in steel is not less than 0.80 %; letters “кп”, “пс”, “сп” - the deoxidation degree of steel is rimmed, semiskilled, and killed respectively.

with dimensional and/or mass tolerances in accordance with:

GOST 8239-89, GOST 8240-97, GOST 8509-93, GOST 8510-86, GOST 26020-83

A.6.3 Acceptable Russian structural steel: hollow sections

GOST 10705-80: Electrically welded steel tubes. Specifications

1. Base metal with heat treatment for hot-rolled pipe

Grade	Outer diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
20, 20пс	10 ≤ D ≤ 630	0.17-0.24	0.030	0.035	^	255	412	22	^
Ст4пс, Ст4кп	10 ≤ D ≤ 630	0.18-0.27	0.040	0.050	^	245	412	21	^
Ст4сп	10 ≤ D ≤ 630	0.18-0.27	0.040	0.050	^	255	412	22	

2. Base metal without heat treatment and heat-treated welded connection

Grade	Outer diameter (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
22ГЮ	60 < D ≤ 152	0.15-0.22	0.020	0.010	^	225	490	15	^
	152 < D ≤ 630					344	490	15	^

^ To be specified by the purchaser.

∗ The range of wall thickness is from 1 mm to 32mm.

Note: letter "Ст" - "Steel"; letters "кп", "пс", "сп" - the deoxidation degree of steel is rimmed, semiskilled, and killed respectively; the first two figures - the average mass fraction of carbon (w(C)% × 100); letters "Г", "Ю" – alloying element of Manganese, Aluminum.

with dimensional and/or mass tolerances in accordance with:

GOST 10704-91

GOST 8731-74: Seamless hot-deformed steel pipes. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	e_L (%)	Impact toughness (J)
		C	P	S					
20	2.5 ≤ t ≤ 75	0.17-0.24	0.030	0.035	^	245	412	21	^
10Г2	2.5 ≤ t ≤ 75	0.07-0.15	0.030	0.035	^	265	421	21	^
15ХМ	2.5 ≤ t ≤ 75	0.11-0.18	0.035	0.035	^	225	431	21	^
12ХН2	2.5 ≤ t ≤ 75	0.09-0.16	0.035	0.035	^	392	539	14	^

^ To be specified by the purchaser.

Note: the first two figures - the average mass fraction of carbon (w(C)% × 100); letters "Х", "Г", "М", "Н" – alloy element of Chromium, Manganese, Molybdenum, Nickel; the figure after the letter - approximate mass fraction of allying elements in whole units, and its absence means the mass fraction of alloy element is up to 1.5%.

with dimensional and/or mass tolerances in accordance with:

GOST 8732-78, GOST 9576-75

GOST 30245-2003 - Steel bent closed welded square and rectangular section for building. Specifications

Sections in GOST 30245 must be made of steel sheet delivered in rolls according to GOST 19903, and the chemical and mechanical properties (thickness: 4mm ≤ t ≤ 12mm) should comply to standards listed below:

1. GOST 27772-2015 - Rolled products for steel structural elements. General specifications – Refer to **Section A.6.1**

2. GOST 14637-89 - Rolled plate from carbon steel of general quality. Specifications – Refer to **Section A.6.1**

3. GOST 1050-2013 - Metal products from nonalloyed structural quality and special steels. General specification – Grade 10 and Grade 15, Refer to **Section A.6.5**

4. GOST 19281-2014 - High strength rolled steel. General specification – Refer to **Section A.6.1**

with dimensional and/or mass tolerances in accordance with:

GOST 30245-2003

GOST R 54864-2016: Hot-deformed seamless steel pipes for the welded steel structures. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
C275	3.5 ≤ t ≤ 10	0.22	0.030	0.030	0.42	275	390	24	≥34J @ -20℃
	10 < t ≤ 16					275	380	23	
	16 < t ≤ 20				0.43	275	380	23	
	20 < t ≤ 40					255	370	21	
C285	3.5 ≤ t ≤ 10	0.22	0.030	0.030	0.42	285	400	24	≥34J @ -20℃
	10 < t ≤ 16					275	390	23	
	16 < t ≤ 20				0.43	275	390	23	
	20 < t ≤ 40					255	380	22	
C345	3.5 ≤ t ≤ 10	0.14	0.030	0.030	0.44	345	490	21	≥34J @ -20℃, -40℃
	10 < t ≤ 16					325	470		
	16 < t ≤ 20				0.45	325	470		
	20 < t ≤ 40					305	460		
C375	3.5 ≤ t ≤ 10	0.14	0.030	0.030	0.44	375	510	21	≥34J @ -20℃, -40℃
	10 < t ≤ 16					355	490		
	16 < t ≤ 20				0.45	355	490		
	20 < t ≤ 40					355	480		
C390	3.5 ≤ t ≤ 16	0.12	0.025	0.030	0.45	390	540	20	≥34J @ -20℃, -40℃, -60℃
	16 < t ≤ 40				0.46				
C440	3.5 ≤ t ≤ 16	0.12	0.025	0.030	0.45	440	590	20	≥34J @ -40℃, -60℃
	16 < t ≤ 30				0.46	440	590		
	30 < t ≤ 40					410	570		

^ To be specified by the purchaser.
* At the request of the customer, the mass fraction shall not exceed 0.010% for sulfur and 0.015% for phosphorus.
** For grade C390 and C440, the total mass fraction of sulfur and phosphorus shall not exceed 0.020% (S+P<0.020%).
Note: letter "C" - "Construction".

with dimensional and/or mass tolerances in accordance with:

GOST 32528-2013

A.6.4 Acceptable Russian structural steel: sheet piles

GOST 4781-85: Hot-rolled steel shapes for sheet piles. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
Ст3пс	t = 10	0.14~0.22	0.040	0.050	0.45	245	370~480	26	≥34J @ +20℃ for t≤26mm
Ст3сп	t =10	0.14~0.22	0.040	0.050	0.45	255	380~490	26	≥34J @ +20℃ for t≤26mm

GOST R 53629-2009: Sheet piles of steel cold-formed sections. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
09Г2	t =12, 16, 20	0.12	0.030	0.035	0.43	305	440	21	^
325	t =12, 16, 20	0.22	0.030	0.035	0.43	325	450	21	^
Ст3сп5	t =12, 16, 20	0.14-0.20	0.030	0.040	^	245	370~490	26	≥34J @ 20℃ ≥30J @ 0℃
Ст3Гпс5	t =12, 16, 20	0,14-0,22	0,030	0,040	^	255	390~570	23	≥34J @ 20℃, ≥30J @ 0℃
20сп, 20пс	t =12, 16, 20	0,17-0,24	0,030	0,035	^	245	410	25	^
20Асп, 20Апс	t =12, 16, 20	0,17-0,24	0.025	0.025	^	245	410	25	^

^ To be specified by the purchaser.

Note: letter "Ст" - "Steel"; letters "кп", "пс", "сп" - the deoxidation degree of steel is rimmed, semiskilled, and killed respectively; letter "Г" – alloying element of Manganese; letter "A" - high-quality steel.

with dimensional and/or mass tolerances in accordance with:

GOST 4781-85, GOST R 53629-2009

A.6.5 Acceptable Russian structural steel: solid bars

GOST 535-2005 - Common quality carbon steel bar and shaped sections. General specifications – Refer to **Section A.6.2**

GOST 19281-2014 - High strength rolled steel. General specification – Refer to **Section A.6.2**

GOST 1050-2013: Metal products from nonalloyed structural quality and special steels. General specification

1. In normalized condition

Grade	Chemical composition (%)			Max CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
	C	P	S					
20	0,17-0,24	0,030	0,035	^	245	410	25	^
25	0,22-0,30	0,030	0,035	^	275	450	23	^
30	0,27-0,35	0,030	0,035	^	295	490	21	^
35	0,32-0,40	0,030	0,035	^	315	530	20	^
40	0,37-0,45	0,030	0,035	^	335	570	19	^
45	0,42-0,50	0,030	0,035	^	355	600	16	^
50	0,47-0,55	0,030	0,035	^	375	630	14	^
55	0,52-0,60	0,030	0,035	^	380	650	13	^
58 (55пп)	0,55-0,63	0,030	0,035	^	315	600	12	^
60	0,57-0,65	0,030	0,035	^	400	680	12	^
60пп	0,57-0,65	0,035	0,040	^	355	600	12	^
15Г	0,12-0,19	0,030	0,035	^	245	410	26	^
20Г	0,17-0,24	0,030	0,035	^	275	450	24	^
10Г2	0,07-0,15	0,030	0,035	^	245	420	22	^

2. Basic properties of in heat-treated condition

Grade	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
	C	P	S					
25Г	0,22-0,30	0,030	0,035	^	295	490	22	^
30Г	0,27-0,35	0,030	0,035	^	315	540	20	^
35Г	0,32-0,40	0,030	0,035	^	335	560	18	^
40Г	0,37-0,45	0,030	0,035	^	355	590	17	^
45Г	0,42-0,50	0,030	0,035	^	375	620	15	^
50Г	0,48-0,56	0,030	0,035	^	390	650	13	^
30Г2	0,26-0,35	0,030	0,035	^	345	590	15	^
35Г2	0,31-0,39	0,030	0,035	^	365	620	13	^
40Г2	0,36-0,44	0,030	0,035	^	380	660	12	^
45Г2	0,41-0,49	0,030	0,035	^	400	690	11	^
50Г2	0,46-0,55	0,030	0,035	^	420	740	11	^

(To be continued)

(Continued)

3. Standardized properties of samples cut out from heat-treated billets with dimensions

Grade	Dimension (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
25	d ≤ 16	0,22-0,30	0,030	0,035	^	375	550-700	19	^
	16 < d ≤ 40					315	500-650	21	
30	d ≤ 16	0,27-0,35	0,030	0,035	^	400	600-750	18	^
	16 < d ≤ 40					355	550-700	20	
	40 < d ≤ 100					295	500-650	21	
35	d ≤ 16	0,32-0,40	0,030	0,035	^	430	630-780	17	^
	16 < d ≤ 40					380	600-750	19	
	40 < d ≤ 100					315	550-700	20	
40	d ≤ 16	0,37-0,45	0,030	0,035	^	460	650-800	16	^
	16 < d ≤ 40					400	630-780	18	
	40 < d ≤ 100					355	600-750	19	
45	d ≤ 16	0,42-0,50	0,030	0,035	^	490	700-850	14	^
	16 < d ≤ 40					430	650-800	16	
	40 < d ≤ 100					375	630-780	17	
50	d ≤ 16	0,47-0,55	0,030	0,035	^	520	750-900	13	^
	16 < d ≤ 40					460	700-850	15	
	40 < d ≤ 100					400	650-800	16	
55	d ≤ 16	0,52-0,60	0,030	0,035	^	550	800-950	12	^
	16 < d ≤ 40					490	750-900	14	
	40 < d ≤ 100					420	700-850	15	
60	d ≤ 16	0,57-0,65	0,030	0,035	^	580	850-1000	11	^
	16 < d ≤ 40					520	800-950	13	
	40 < d ≤ 100					450	750-900	14	

^ To be specified by the purchaser.

Note: the first two figures - the average mass fraction of carbon (w(C)% × 100); letter "Г" – alloy element of Manganese; the figure after the letter - approximate mass fraction of allying elements in whole units.

with dimensional and/or mass tolerances in accordance with:

GOST 103-2006, GOST 2590-2006, GOST 2591-2006

A.6.6 Acceptable Russian structural steel: strips for cold formed open sections

GOST 27772-2015 - Rolled products for steel structural elements. General specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact Toughness (J)
		C	P	S					
C235	2 ⩽ t ⩽ 3.9	0.22	0.040	0.040	^	235	360	^	^
	t = 4.0					235	360		
C245	2 ≤ t ≤ 3.9	0.22	0.040	0.025	^	245	370	20	≥34J @ 0℃
	4 ≤ t ≤ 30					235	370	24	
C255	2 ⩽ t ⩽ 3.9	0.17	0.035	0.025	^	255	380	20	^
	4 ⩽ t ⩽ 10					245	380	25	≥34J @ 0℃ ≥34J @ -20℃
C345	2 ⩽ t ⩽ 3.9	0.15	0.030	0.025	0.45	345	490	21	^
	4 ≤ t ≤ 10					345	490	21	≥34J @ -20℃ ≥34J @ -40℃
C355	8 ≤ t ≤ 16	0.14	0.025	0.025	0.45	355	470	21	≥34J @ -20℃ ≥34J @ -40℃
C355-1	8 ≤ t ≤ 16	0.15	0.017	0.015	0.45	355	470	21	≥34J @ -20℃ ≥34J @ -40℃
C355K	8 ≤ t ≤ 16	0.15	0.020	0.015	0.45	355	470	21	≥34J @ -20℃ ≥34J @ -40℃
C355П	8 ≤ t ≤ 16	0.10	0.020	0.015	0.45	355	470	21	≥34J @ -20℃ ≥34J @ -40℃
C390 (C390-1)	8 ≤ t ≤ 50	0.12	0.017	0.010	0.46	390	520	20	≥34J @ -40℃ ≥34J @ -60℃
C440	8 ≤ t ≤ 50	0.12	0.017	0.010	0.46	440	540	20	≥66J @ -40℃ ≥66J @ -60℃
C550	8 ≤ t ≤ 50	0.10	0.015	0.007	0.47	540	640	17	≥66J @ -40℃ ≥66J @ -60℃
C590	8 ≤ t ≤ 40	0.10	0.015	0.004	0.51	590	685	14	≥66J @ -40℃ ≥66J @ -60℃

^ To be specified by the purchaser.

Note: letter “C” - “Structure Steel”; figure “1” – another option of chemical composition; letter “K” - the steel of improved corrosion resistance; letter “П” - the steel of improved fire resistance.

GOST 1050-2013: Metal products from nonalloyed structural quality and special steels. General specification

1. In normalized condition

Grade	Chemical composition (%)			Max CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
	C	P	S					
10	0,07-0,14	0,030	0,035	^	205	330	31	^
15	0,12-0,19	0,030	0,035	^	225	370	27	^
20	0,17-0,24	0,030	0,035	^	245	410	25	^
15Г	0,12-0,19	0,030	0,035	^	245	410	26	^
20Г	0,17-0,24	0,030	0,035	^	275	450	24	^
10Г2	0,07-0,15	0,030	0,035	^	245	420	22	^

^ To be specified by the purchaser.

* Steels in this table are in normalized condition.

Note: the first two figures - the average mass fraction of carbon (w(C)% × 100); letter “Г” – alloy element of Manganese; the figure after the letter - approximate mass fraction of allying elements in whole units.

GOST 535-2005 - Common quality carbon steel bar and shaped sections. General specifications

Grate	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
Ст1пс, Ст1сп	t ≤ 10	0.06~0.12	0.040	0.050	0.45	205	315~410	34	^
Ст2кп	t ≤ 10	0.09~0.15	0.040	0.050	0.45	215	325~410	33	^
Ст2пс, Ст2сп	t ≤ 10	0.09~0.15	0.040	0.050	0.45	225	335~430	32	^
Ст3кп	t ≤ 10	0.14~0.22	0.040	0.050	0.45	235	360~460	27	^
Ст3пс	t ≤ 10	0.14~0.22	0.040	0.050	0.45	245	370~480	26	≥34J @ +20℃ for t≤26mm
Ст3сп	t ≤ 10	0.14~0.22	0.040	0.050	0.45	255	380~490	26	≥34J @ +20℃ for t≤26mm
Ст3Гпс	t ≤ 10	0.14~0.22	0.040	0.050	0.45	^	370~490	26	≥34J @ +20℃, for t≤26mm
Ст3Гсп	t ≤ 20	0.14~0.22	0.040	0.050	0.45	^	390~570	^	≥34J @ +20℃ for t≤26mm
Ст4пс, Ст4сп	t ≤ 10	0.18~0.27*	0.040	0.050	0.45	265	410~530	24	^
Ст5Гпс	t ≤ 10	0.22~0.30*	0.040	0.050	0.45	^	450~590	20	^

^ To be specified by the purchaser.
* The mass fraction of carbon for welded structures must not exceed 0.22%.
Note: letter “Ст” - “Steel”; letter 'Г” - the mass fraction of manganese in steel is not less than 0.80 %; letters “кп”, “пс”, “сп” - the deoxidation degree of steel is rimmed, semiskilled, and killed respectively.

GOST 11474-76: Bent-steel sections. Specifications:

Sections in GOST 11474 must be made of steel sheet grades (Us ≤ 588 N/mm²) according to standards list below

GOST 14637-89, GOST 16523-97, GOST 1577-93, GOST 17066-94, and GOST 19281-2014.

GOST 14637-89 - Rolled plate from carbon steel of general quality. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact Toughness (J)
		C	P	S					
Ст2кп	t ≤20	0.09~0.15	0.040	0.050	^	215	320~410	33	^
Ст2пс, Ст2сп	t ≤20	0.09~0.15	0.040	0.050	^	225	330~430	32	^
Ст3кп	t ≤ 20	0.14~0.22	0.030	0.040	^	235	360~460	27	^
Ст3пс, Ст3сп	t ≤ 20	0.14~0.22	0.030	0.040	^	245	370~480	26	≥34J @ 20℃ ≥30J @ 0℃
Ст3Гпс	t ≤20	0.14~0.22	0.030	0.040	^	245	370~490	26	≥34J @ 20℃ ≥30J @ 0℃
Ст3Гсп	t ≤20	0.14~0.22	0.030	0.040	^	255	390~570	23	≥34J @ 20℃ ≥30J @ 0℃
Ст4пс, Ст4спs	t ≤ 20	0.18~0.27*	0.030	0.040	^	265	410~530	24	^
Ст5Гпс	t ≤20	0.22~0.30*	0.030	0.040	^	285	450~590	20	^

^ To be specified by the purchaser.
* The mass fraction of carbon for welded structures must not exceed 0.22%.
** At the request of the customer, the mass fraction shall not exceed 0.040% for sulfur and 0.030% for phosphorus in rolled steel of categories 1 to 5, and each of these elements shall not exceed 0.025% in rolled steel of category 6.
Note: letter “Ст” - “Steel”; letter “Г” - the mass fraction of manganese in steel is not less than 0.80 %; letters “кп”, “пс”, “сп” - the deoxidation degree of steel is rimmed, semiskilled, and killed respectively.

GOST 16523-97: Rolled sheets from quality and ordinary carbon steel for purposes. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)	Impact toughness (J)
		C	P	S					
K260B	t ≤ 2	0.05~0.12	0.030	0.035	^	^	260 - 380	25	^
	2 < t ≤ 3.9							28	
K270B	t ≤ 2	0.05~0.14	0.030	0.035	^	^	270 - 410	24	^
	2 < t ≤ 3.9							26	
OK300B	t ≤ 2	0.06~0.12	0.040	0.050	^	215	300 - 480	21	^
	2 < t ≤ 3.9							23	
K310B	t ≤ 2	0.12~0.19	0.030	0.035	^	^	310 - 440	23	^
	2 < t ≤ 3.9							25	
K330B	t ≤ 2	0.12~0.24	0.030	0.035	^	^l	330 - 460	23	^
	2 < t ≤ 3.9							24	
K350B	t ≤ 2	0.17~0.24	0.030	0.035	^	^	350 - 500	22	^
	2 < t ≤ 3.9							23	
OK360B	t ≤ 2	0.14~0.22	0.040	0.050	^	235	360 - 530	20	^
	2 < t ≤ 3.9							22	

^ To be specified by the purchaser.
* Steels in this table are hot rolled products.
Note: the three figures - the lower limit of tensile strength; letter “OK” - ordinary quality carbon steel; letter “K” - quality carbon steel.

GOST 17066-94: Rolled sheet of high-strength steel. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	□ (%)	Impact toughnes s (J)
		C	P	S					
295	0.5 ≤ t ≤ 3.9	0.16	0.035	0.040	^	295	440	20	^
315	0.5 ≤ t ≤ 3.9	0.16	0.035	0.040	^	315	460	20	^
345	0.5 ≤ t ≤ 3.9	0.18	0.035	0.040	^	345	490	19	^
355	0.5 ≤ t ≤ 3.9	0.20	0.035	0.040	^	355	510	18	^
390	0.5 ≤ t ≤ 3.9	0.22	0.035	0.040	^	390	530	18	^

^ To be specified by the purchaser.
* Steels in this table are hot rolled products.
** At the request of the customer, the mass fraction shall not exceed 0.035% for sulfur and 0.030% for phosphorus.

GOST 1577-93 - Rolled sheets and wide strips of structural quality steel. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm^2)	U_s (N/mm^2)	ε_L (%)		Impact toughness (J)
		C	P	S				along rolled direction	across rolled direction	
20	6 ≤ t ≤ 60	0.17~0.24	0.030	0.035	^	230	400~550	27	25	^

^ To be specified by the purchaser.
* Steels in this table are in normalized condition.
Note: the two figures - the average mass fraction of carbon (w(C)% × 100).

GOST 19281-2014 - High strength rolled steel. General specification

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact Toughness (J)
		C	P	S					
265	t ≤ 160	0.14	0.030	0.035	0.43	265	430	21	≥34J @ 0℃ and ≥29J @-20℃ for t ≤ 20mm
295	t ≤ 100	0.14	0.030	0.035	0.43	295	430	21	≥34J @ 0℃, ≥29J @-20℃
315	t ≤ 60	0.18	0.030	0.035	0.43	315	450	21	≥34J @ 0℃, ≥29J @-20℃
325	t ≤ 60	0.22	0.030	0.035	0.43	325	450	21	≥34J @ 0℃, ≥29J @-20℃
345	t ≤ 50	0.22	0.030	0.035	0.46	345	490	21	≥34J @ -20℃ for t≤12mm, ≥39J @ 0℃ & -20℃ for 12mm<t≤50mm
355	t ≤ 50	0.22	0.030	0.035	0.46	355	490	20	≥34J @ 0℃, ≥29J @-20℃
375	t ≤ 50	0.22	0.030	0.035	0.46	375	510	20	≥29J @-20℃
390	t ≤ 50	0.22	0.030	0.035	0.48	390	510	19	≥29J @ -20℃ for t≤10mm, ≥39J @ 0℃ & ≥29J @ -20℃ for 10mm<t≤15mm, ≥39J @ 0℃ & -20℃ for 15mm<t≤50mm

with dimensional and/or mass tolerances in accordance with:

GOST 8278-83,GOST 8281-80, GOST 8282-83, GOST 8283-93, GOST 13229-78, GOST 19771-93, GOST 19772-93, GOST 7511-73.

A.6.7 Acceptable Russian strips for cold-formed steel profiled sheetings

GOST 16523-97: Rolled sheets from quality and ordinary carbon steel for purposes. Specifications

1. Hot rolled steel

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td rowspan="2">К260В</td><td>t ≤ 2</td><td rowspan="2">0.05~0.12</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">260 - 380</td><td>25</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>28</td></tr>
<tr><td rowspan="2">К270В</td><td>t ≤ 2</td><td rowspan="2">0.05~0.14</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">270 - 410</td><td>24</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>26</td></tr>
<tr><td rowspan="2">ОК300В</td><td>t ≤ 2</td><td rowspan="2">0.06~0.12</td><td rowspan="2">0.040</td><td rowspan="2">0.050</td><td rowspan="2">^</td><td rowspan="2">215</td><td rowspan="2">300 - 480</td><td>21</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>23</td></tr>
<tr><td rowspan="2">К310В</td><td>t ≤ 2</td><td rowspan="2">0.12~0.19</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">310 - 440</td><td>23</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>25</td></tr>
<tr><td rowspan="2">К330В</td><td>t ≤ 2</td><td rowspan="2">0.12~0.24</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^|</td><td rowspan="2">330 - 460</td><td>23</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>24</td></tr>
<tr><td rowspan="2">К350В</td><td>t ≤ 2</td><td rowspan="2">0.17~0.24</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">350 - 500</td><td>22</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>23</td></tr>
<tr><td rowspan="2">ОК360В</td><td>t ≤ 2</td><td rowspan="2">0.140~0.22</td><td rowspan="2">0.040</td><td rowspan="2">0.050</td><td rowspan="2">^</td><td rowspan="2">235</td><td rowspan="2">360 - 530</td><td>20</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>22</td></tr>
</table>

2. Cold rolled steel

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Thickness (mm)</th><th colspan="3">Chemical composition (%)</th><th rowspan="2">Max. CEV (%)</th><th rowspan="2">Y_s (N/mm^2)</th><th rowspan="2">U_s (N/mm^2)</th><th rowspan="2">ε_L (%)</th><th rowspan="2">Impact toughness (J)</th></tr>
<tr><th>C</th><th>P</th><th>S</th></tr>
<tr><td rowspan="2">К260В</td><td>t ≤ 2</td><td rowspan="2">0.05~0.12</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">260 - 380</td><td>26</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>29</td></tr>
<tr><td rowspan="2">К270В</td><td>t ≤ 2</td><td rowspan="2">0.05~0.14</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">270 - 410</td><td>25</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>28</td></tr>
<tr><td rowspan="2">ОК300В</td><td>t ≤ 2</td><td rowspan="2">0.06~0.12</td><td rowspan="2">0.040</td><td rowspan="2">0.050</td><td rowspan="2">^</td><td rowspan="2">215</td><td rowspan="2">300 - 480</td><td>24</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>26</td></tr>
<tr><td rowspan="2">К310В</td><td>t ≤ 2</td><td rowspan="2">0.12~0.19</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">310 - 440</td><td>24</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>27</td></tr>
<tr><td rowspan="2">К330В</td><td>t ≤ 2</td><td rowspan="2">0.12~0.24</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">330 - 460</td><td>24</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>25</td></tr>
<tr><td rowspan="2">К350В</td><td>t ≤ 2</td><td rowspan="2">0.17~0.24</td><td rowspan="2">0.030</td><td rowspan="2">0.035</td><td rowspan="2">^</td><td rowspan="2">^</td><td rowspan="2">350 - 500</td><td>23</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>24</td></tr>
<tr><td rowspan="2">ОК360В</td><td>t ≤ 2</td><td rowspan="2">0.140~0.22</td><td rowspan="2">0.040</td><td rowspan="2">0.050</td><td rowspan="2">^</td><td rowspan="2">235</td><td rowspan="2">360 - 530</td><td>22</td><td rowspan="2">^</td></tr>
<tr><td>2 < t ≤ 3.9</td><td>24</td></tr>
</table>

^ To be specified by the purchaser.
Note: the three figures - the lower limit of tensile strength; letter “ОК” - ordinary quality carbon steel; letter “К” - quality carbon steel.

GOST 17066-94: Rolled sheet of high-strength steel. Specifications

1. Hot rolled steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
295	0.5 ≤ t ≤ 3.9	0.16	0.035	0.040	^	295	440	20	^
315	0.5 ≤ t ≤ 3.9	0.16	0.035	0.040	^	315	460	20	^
345	0.5 ≤ t ≤ 3.9	0.18	0.035	0.040	^	345	490	19	^
355	0.5 ≤ t ≤ 3.9	0.20	0.035	0.040	^	355	510	18	^
390	0.5 ≤ t ≤ 3.9	0.22	0.035	0.040	^	390	530	18	^

2. Cold rolled steel

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
295	0.5 ≤ t ≤ 3.9	0.16	0.035	0.040	^	295	410	20	^
315	0.5 ≤ t ≤ 3.9	0.16	0.035	0.040	^	315	430	20	^
345	0.5 ≤ t ≤ 3.9	0.18	0.035	0.040	^	345	460	19	^
355	0.5 ≤ t ≤ 3.9	0.20	0.035	0.040	^	355	480	18	^
390	0.5 ≤ t ≤ 3.9	0.22	0.035	0.040	^	390	500	18	^

^ To be specified by the purchaser.
* At the request of the customer, the mass fraction shall not exceed 0.035% for sulfur and 0.030% for phosphorus.

GOST R 52246-2004: Hot-dip zinc-coated steel sheet. Specifications

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
02	t ≤ 0.7	0.12	0.040	0.040	^	^	270 - 500	20	^
	0.7 < t ≤ 1.5							22	
	1.5 < t ≤ 2.0							^	
	2.0 < t ≤ 4.5							^	
03	t ≤ 0.7	0.12	0.030	0.030	^	^	270 - 420	24	^
	0.7 < t ≤ 1.5							26	
	1.5 < t ≤ 2.0							28	
	2.0 < t ≤ 4.5							30	
04	t ≤ 0.7	0.10	0..030	0.030	^	≤ 260	270 - 380	28	^
	0.7 < t ≤ 1.5							30	
	1.5 < t ≤ 2.0							32	
	2.0 < t ≤ 4.5							^	
05	t ≤ 0.7	0.08	0.030	0.030	^	≤ 220	270 - 350	34	
	0.7 < t ≤ 1.5							36	
	1.5 < t ≤ 2.0							38	
	2.0 < t ≤ 4.5							^	
220	t ≤ 0.7	0.22	0.040	0.040	^	≥220	≥300	18	^
	0.7 < t ≤ 1.5							20	
	1.5 < t ≤ 2.0							20	
	2.0 < t ≤ 4.5							20	

(To be continued)

(Continued)

Grade	Thickness (mm)	Chemical composition (%)			Max. CEV (%)	Y_s (N/mm²)	U_s (N/mm²)	ε_L (%)	Impact toughness (J)
		C	P	S					
250	t ≤ 0.7	0.22	0.040	0.040	^	≥250	≥330	17	^
	0.7 < t ≤ 1.5							19	
	1.5 < t ≤ 2.0							19	
	2.0 < t ≤ 4.5							19	
280	t ≤ 0.7	0.25	0.040	0.040	^	≥280	≥360	16	^
	0.7 < t ≤ 1.5							18	
	1.5 < t ≤ 2.0							18	
	2.0 < t ≤ 4.5							18	
320	t ≤ 0.7	0.25	0.040	0.040	^	≥320	≥390	15	^
	0.7 < t ≤ 1.5							17	
	1.5 < t ≤ 2.0							17	
	2.0 < t ≤ 4.5							17	
350	t ≤ 0.7	0.25	0.040	0.040	^	≥350	≥420	14	^
	0.7 < t ≤ 1.5							16	
	1.5 < t ≤ 2.0							16	
	2.0 < t ≤ 4.5							16	

with dimensional and/or mass tolerances in accordance with:

GOST 19903-2015, GOST 19904.

A.6.8 Acceptable Russian stud connectors

Stud connectors manufactured to:-

- GOST 1759.0-87
- GOST R ISO 898-1-2014

A.6.9 Acceptable Russian non-preloaded bolting assemblies

Bolts manufactured to:-

- GOST 1759.0-87
- GOST R ISO 898-1-2014
- GOST 18126-94

Nuts manufactured to:-

- GOST 1759.0-87
- GOST R ISO 898-2-2013
- GOST ISO 4032-2014
- GOST ISO 8673-2014
- GOST 10605-94
- GOST 18126-94

Washers manufactured to:-

- GOST 18123-82
- GOST 11850-72

A.6.10 Acceptable Russian preloaded bolting assemblies

- GOST R 52643-2006

A.6.11 Acceptable Russian welding consumables

Electrodes manufactured to:-

- GOST 9467-75
- GOST 5.1215-72

Wires manufactured to:-

- GOST 2246-70
- GOST 26271-84
- GOST 26101-84

Flues manufactured to:-

- GOST 9087-81

Appendix B List of reference standards

B.1 British/European standards

B.2 American standards

B.3 Japanese standards

B.4 Australian/New Zealand standards

B.5 Chinese standards

B.6 Russian standards

Appendix B List of materials specifications

This Appendix covers British/European, American, Japanese, Australian/New Zealand, Chinese, and Russian standards used as materials specifications for this document. The specifications listed in this appendix are only current and confirmed at the time of drafting of this document and should be updated in accordance with the latest version of the respective specifications.

B.1 British/European specifications

The following British/European standards are published by the British Standards Institution, London, United Kingdom.

B.1.1 British/European specifications on design of steel structures

BS EN 1993-1-1:2005 (A1:2004)	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for Buildings
BS EN 1993-1-3:2006	Eurocode 3: Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting
BS EN 1993-1-8:2005	Eurocode 3: Design of steel structures - Part 1-8: Design of joints
BS EN 1993-1-10:2005	Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through thickness properties
BS EN 1993-1-12:2007	Eurocode 3: Design of steel structures - Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S 700
BS EN 1994-1-1:2004	Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings

B.1.2 British/European specifications on steel materials

BS 7668:2016	Weldable structural steels - Hot finished structural hollow sections in weather resistant steels - Specification
BS EN 10020:2000	Definition and classification of grades of steel
BS EN 10021:2006	General technical delivery requirements for steel and iron products
BS EN 10025-1:2004	Hot rolled products of structural steels - Part 1: General technical delivery conditions
BS EN 10025-2:2019	Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels
BS EN 10025-3:2019	Hot rolled products of structural steels - Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels
BS EN 10025-4:2019	Hot rolled products of structural steels - Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels
BS EN 10025-5:2019	Hot rolled products of structural steels - Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance

BS EN 10025-6:2019	Hot rolled products of structural steels - Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition
BS EN 10027-1:2016	Designation systems for steels - Part 1: Steel names
BS EN 10079:2007	Definition of steel products
BS EN 10149-1:2013	Specification for hot-rolled flat products made of high yield strength steels for cold forming - Part 1: General delivery conditions
BS EN 10149-2:2013	Specification for hot-rolled flat products made of high yield strength steels for cold forming - Part 2: Delivery conditions for thermomechanically rolled steels
BS EN 10149-3:2013	Specification for hot-rolled flat products made of high yield strength steels for cold forming - Part 3. Delivery conditions for normalized or normalized rolled steels
BS EN 10051:2010	Continuously hot-rolled uncoated plate, sheet and strip of non-alloy and alloy steels - Tolerances on dimensions and shape
BS EN 10164:2018	Steel products with improved deformation properties perpendicular to the surface of the product - Technical delivery conditions
BS EN 10210-1:2006	Hot finished structural hollow sections of non-alloy and fine grain steels - Part 1: Technical delivery conditions
BS EN 10219-1:2006	Cold formed welded structural hollow sections of non-alloy and fine grain steels - Part 1: Technical delivery conditions
BS EN 10248-1:1996	Hot rolled steel sheet piling of non alloy steels – Part 1: Technical delivery conditions
BS EN 10249-1:1996	Cold formed steel piling of non alloy steels – Part 1: Technical delivery conditions
BS EN 10268:2006 (A1:2003)	Cold rolled steel flat products with high yield strength for cold forming - Technical delivery conditions
BS EN 10326:2004	Continuously hot-dip coated strip and sheet of structural steels - Technical delivery conditions
BS EN 10346:2015	Continuously hot-dip coated steel flat products - Technical delivery conditions

B.1.3 British/European specifications on dimensions and shapes

BS EN 10017:2004	Steel rod for drawing and/or cold rolling Dimensions and tolerances
BS EN 10024:1995	Hot rolled taper flange I sections - Tolerances on shape and dimensions
BS EN 10029:2010	Specification for tolerances on dimensions, shape and mass for hot rolled steel plates 3 mm thick or above
BS EN 10034:1993	Structural steel I and H sections - Tolerances on shape and dimensions
BS EN 10051:2010	Continuously hot-rolled uncoated plate, sheet and strip of non-alloy and alloy steels - Tolerances on dimensions and shape
BS EN 10055:1996	Hot rolled steel equal flange tees with radiused root and toes - Dimensions and tolerances on shape and dimensions
BS EN 10056-2:1993	Specification for structural steel equal and unequal leg angles - Part 2: Tolerances on shape and dimensions

BS EN 10058:2018	Hot rolled flat steel bars and steel wide flats for general purposes – Dimensions and tolerances on shape and dimensions
BS EN 10059:2003	Hot rolled square steel bars for general purposes – Dimensions and tolerances on shape and dimensions
BS EN 10060:2003	Hot rolled round steel bars for general purposes – Dimensions and tolerances on shape and dimensions
BS EN 10131:2006	Cold rolled uncoated and zinc or zinc-nickel electrolytically coated low carbon and high yield strength steel flat products for cold forming Tolerances on dimensions and shape
BS EN 10140:2006	Cold rolled narrow steel strip Tolerances on dimensions and shape
BS EN 10143:2006	Continuously hot-dip coated steel sheet and strip – Tolerances on dimensions and shape
BS EN 10210-2:2019	Hot finished structural hollow sections - Part 2: Tolerances, dimensions and sectional properties
BS EN 10219-2:2019	Cold formed welded structural hollow sections - Part 2: Tolerances, dimensions and sectional properties
BS EN 10248-2:1996	Hot rolled steel sheet piling of non-alloy steels - Part 2: Tolerances on shape and dimensions
BS EN 10249-2:1996	Cold formed steel sheet piling of non-alloy steels - Part 2: Tolerances on shape and dimensions
BS EN 10279:2000	Hot rolled steel channels - Tolerances on shape, dimension and mass

B.1.4 British/European specifications on bolting assemblies

General information

BS EN 15048-1:2016	Non-preloaded structural bolt assemblies – Part 1: General requirements
BS EN ISO 898-1:2013	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs
BS EN ISO 898-2:2012	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread
BS EN ISO 16426:2002 (R2008)(R2018)	Fasteners - Quality assurance system

Non-preloaded assemblies

BS 4190:2014	ISO metric black hexagon bolts, screws and nuts - Specification
BS 7419:2012	Specification for holding down bolts
BS EN ISO 4014:2011	Hexagon head bolts - Product grades A and B
BS EN ISO 4016:2011	Hexagon head bolts - Product grade C
BS EN ISO 4017:2014	Hexagon head screws - Product grades A and B
BS EN ISO 4018:2011	Hexagon head screws - Product grade C
BS EN ISO 4032:2012	Hexagon regular nuts (style 1) - Product grades A and B
BS EN ISO 4033:2012	Hexagon high nuts (style 2) - Product grades A and B

BS EN ISO 4034:2012	Hexagon regular nuts (style 1) - Product grade C
BS EN ISO 898-3:2018 (A1:2021)	Fasteners - Mechanical properties of fasteners made of carbon steel and alloy steel - Part 3: Flat washers with specified property classes
BS EN ISO 7091:2000	Plain washers - Normal series - Product grade C
BS EN ISO 7092:2000	Plain washers - Small series - Product grade A
BS EN ISO 7093-1:2000	Plain washers - Large series - Product grade A
BS EN ISO 7093-2:2000	Plain washers - Large series - Product grade C
BS EN ISO 7094:2000	Plain washers - Extra large series - Product grade C

Preloaded assemblies

BS EN 1993-1-8:2005	Eurocode 3: Design of steel structures - Part 1-8: Design of joints
BS EN 14399-1:2005	High-strength structural bolting assemblies for preloading - Part 1: General requirements
BS EN 14399-2:2015	High-strength structural bolting assemblies for preloading - Part 2: Suitability for preloading
BS EN 14399-3:2015	High-strength structural bolting assemblies for preloading - Part 3: System HR - Hexagon bolt and nut assemblies
BS EN 14399-4:2015	High-strength structural bolting assemblies for preloading - Part 4: System HV - Hexagon bolt and nut assemblies
BS EN 14399-5:2015	High-strength structural bolting assemblies for preloading - Part 5: Plain washers
BS EN 14399-6:2015	High-strength structural bolting assemblies for preloading - Part 6: Plain chamfered washers
BS EN 14399-7:2018	High-strength structural bolting assemblies for preloading - Part 7: System HR - Countersunk head bolt and nut assemblies
BS EN 14399-8:2018	High-strength structural bolting assemblies for preloading- Part 8: System HV - Hexagon fit bolt and nut assemblies
BS EN 14399-9:2018	High-strength structural bolting assemblies for preloading - Part 9: System HR or HV - Direct tension indicators for bolt and nut assemblies
BS EN 14399-10:2018	High-strength structural bolting assemblies for preloading - Part 10: System HRC. Bolt and nut assemblies with calibrated preload

B.1.5 British/European specifications on welding consumables

BS EN ISO 14174:2019	Welding consumables - Fluxes for submerged arc welding and electroslag welding - Classification
BS EN ISO 636:2017	Welding consumables - Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine-grain steels - Classification
BS EN ISO 2560:2020	Welding consumables - Covered electrodes for manual metal arc welding of non alloy and fine grain steels - Classification
BS EN ISO 14171:2016	Welding consumables – Solid wires electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non-alloy and fine grain steels – Classification

BS EN ISO 14341:2020	Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels - Classification
BS EN ISO 14343:2017	Welding consumables - Wire electrodes, strip electrodes, wires and rods for arc welding of stainless and heat resisting steels - Classification
BS EN ISO 15792-1: 2020	Welding consumables - Test methods Part 1: Preparation of all-weld metal test pieces and specimens in steel, nickel and nickel alloys
BS EN ISO 15792-2: 2020	Welding consumables - Test methods Part 2: Preparation of single-run and two-run technique test pieces and specimens in steel
BS EN ISO 15792-3: 2011	Welding consumables - Test methods - Part 3: Classification testing of positional capacity and root penetration of welding consumables in a fillet weld
BS EN ISO 16834:2012	Welding consumables - Wire electrodes, wires, rods and deposits for gas shielded arc welding of high strength steels - Classification
BS EN ISO 17632:2015	Welding consumables - Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels - Classification
BS EN ISO 17633:2018 (A1:2021)	Welding consumables – Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels – Classification
BS EN ISO 17634:2015	Welding consumables - Tubular cored electrodes for gas shielded metal arc welding of creep-resisting steels - Classification
BS EN ISO 18274:2010	Welding consumables – Solid wire electrodes, solid strip electrodes, solid wires and solid rods for fusion welding of nickel and nickel alloys– Classification
BS EN ISO 21952:2012	Welding consumables - Wire electrodes, wires, rods and deposits for gas shielded arc welding of creep-resisting steels - Classification
BS EN ISO 24373:2018	Welding consumables - Solid wires and rods for fusion welding of copper and copper alloys - Classification
BS EN ISO 24598:2019	Welding consumables - Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of creep-resisting steels - Classification
BS EN ISO 26304:2018	Welding consumables - Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels - Classification

B.1.6 British/European specifications on strips for cold-formed profiled steel sheetings

BS EN 10346:2015	Continuously hot-dip coated steel flat products for cold forming - Technical delivery conditions
BS EN 10143:2006	Continuously hot-dip coated steel sheet and strip - Tolerances on dimensions and shape

B.1.7 British/European specifications on stud connectors

BS EN ISO 13918:2018 (A1:2021)	Welding – Studs and ceramic ferrules for arc stud welding
BS EN ISO 898-1:2013	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread

B.1.8 British/European specifications on material testing

BS EN ISO 898-2	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread
BS EN ISO 148-1:2016	Metallic materials - Charpy pendulum impact test - Part 1: Test method
BS EN ISO 2566-1:2021	Steel - Conversion of elongation values - Part 1: Carbon and low-alloy steels
BS EN ISO 6506-1:2014	Metallic materials - Brinell hardness test - Part 1: Test method
BS EN ISO 6507-1:2018	Metallic materials - Vickers hardness test - Part 1: Test method
BS EN ISO 6508-1:2016	Metallic materials - Rockwell hardness test - Part 1: Test method
BS EN ISO 6892-1:2019	Metallic materials - Tensile testing Part 1: Method of test at room temperature
BS EN ISO 8501-1:2007	Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
BS EN ISO 14284:2002	Steel and iron - Sampling and preparation of samples for the determination of chemical composition
BS EN ISO 15792-1:2020	Welding consumables - Test methods - Part 1: Preparation of all-weld metal test pieces and specimens in steel, nickel and nickel alloys

B.1.9 British/European specifications on inspection documents

BS EN 10168:2004 (R2019)	Steel products - Inspection documents - List of information and description
BS EN 10204:2004	Metallic products - Types of inspection documents

B.2 American specifications

The following American specifications are published by the American Institute of Steel Construction, Chicago, Illinois; the American Petroleum Institute, Washington, D.B.; the American Society for Testing and Materials, West Conshohocken, Pennsylvania; the American Welding Society, Miami, Florida, United States of America.

B.2.1 American specifications on design of steel structures

AISC 303:2016	Code of Standard Practice for Steel Buildings and Bridges
AISC 360:2016	Specification for Structural Steel Buildings

B.2.2 American specifications on steel materials

API SPEC 5L:2018	Line Pipe
ASTM A36/A36M:2019	Standard Specification for Carbon Structural Steel
ASTM A53:2020	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A109:2016 (R2018)	Standard Specification for Steel, Strip, Carbon (0.25 Maximum Percent), Cold-Rolled
ASTM A242:2013 (R2018)	Standard Specification for High-Strength Low-Alloy Structural Steel
ASTM A268:2020	Standard Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service
ASTM A283:2018	Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
ASTM A328:2013 (R2018)	Standard Specification for Steel Sheet Piling
ASTM A333:2018	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness
ASTM A423:2019	Standard Specification for Seamless and Electric-Welded Low-Alloy Steel Tubes
ASTM A500:2021	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A501:2021	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
ASTM A514:2018 (E2019)	Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
ASTM A529:2019	Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality
ASTM A572:2021	Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
ASTM A573:2020	Standard Specification for Structural Carbon Steel Plates
ASTM A588:2019	Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance

ASTM A595:2018	Standard Specification for Steel Tubes, Low-Carbon or High-Strength Low-Alloy, Tapered for Structural Use
ASTM A606:2018	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot- Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
ASTM A618:2021	Standard Specification for Hot-Formed Welded and Seamless High-Strength Low-Alloy Structural Tubing
ASTM A653:2020	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A673:2017	Standard Specification for Sampling Procedure for Impact Testing of Structural Steel
ASTM A709:2021	Standard Specification for Structural Steel for Bridges
ASTM A792:2021	Standard Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
ASTM A847:2021	Standard Specification for Cold-Formed Welded and Seamless High-Strength, Low- Alloy Structural Tubing with Improved Atmospheric Corrosion Resistance
ASTM A857:2019	Standard Specification for Steel Sheet Piling, Cold Formed, Light Gage
ASTM A871:2020	Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Atmospheric Corrosion Resistance
ASTM A875:2021	Standard Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process
ASTM A913:2019	Standard Specification for High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)
ASTM A945:2016 (R2021)	Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness
ASTM A992:2020	Standard Specification for Structural Steel Shapes
ASTM A1003:2015	Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members
ASTM A1008:2021	Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Required Hardness, Solution Hardened, and Bake Hardenable
ASTM A1011:2018	Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High- Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
ASTM A1046:2019	Standard Specification for Steel Sheet, Zinc-Aluminum-Magnesium Alloy-Coated by the Hot-Dip Process
ASTM A1066:2022	Standard Specification for High-Strength Low Alloy Structural Steel Plate Produced by Thermo-Mechanical Controlled Process (TMCP)

B.2.3 American specifications on dimensions and shapes

ASTM A6:2021	Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
ASTM A450:2021	Standard Specification for General Requirements for Carbon and Low Alloy Steel Tubes
ASTM A568 REV A:2019	Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low- Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
ASTM A924 -2022	Standard Specification for General Requirements for Steel Sheet, Metallic- Coated by the Hot-Dip Process
ASTM A999:2018	Standard Specification for General Requirements for Alloy and Stainless Steel Pipe

B.2.4 American specifications on bolting assemblies

Non-preloaded assemblies

ASTM A193:2020	Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
ASTM A194 REV A:2020	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High
	Pressure or High Temperature Service, or Both
ASTM A307:2021	Standard Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength
ASTM F3125:2021	Standard Specification for High Strength Structural Bolts and Assemblies, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi (830 MPa and 1040 MPa) Minimum Tensile Strength
ASTM A354:2017 (E2017) (E2018)	Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
ASTM A449:2014 (R2020)	Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
ASTM A563 REV A:2021	Standard Specification for Carbon and Alloy Steel Nuts
ASTM F436:2019	Standard Specification for Hardened Steel Washers

Preloaded assemblies

ASTM A193:2020	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications
ASTM A194 REV A:2020	Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
ASTM A354:2017 (E2017) (E2018)	Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
ASTM A563 REV A:2021	Standard Specification for Carbon and Alloy Steel Nuts
ASTM F436:2019	Standard Specification for Hardened Steel Washers

ASTM F959:2019	Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners

B.2.5 American specifications on welding consumables

AWS D1.3:2018	Structural welding code – Sheet steel
AWS A5.1:2012	Specification for Carbon Steel Electrodes for Shielded Metal ArcWelding
AWS A5.9:2017	Welding Consumables — Wire Electrodes, Strip Electrodes, Wires, and Rods for Arc Welding of Stainless and Heat Resisting Steels — Classification
AWS A5.29:2012	Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding

B.2.6 American specifications on strips cold-formed profiled sheetings

ASTM A606:2018	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
ASTM A653:2020	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A1046:2019	Standard Specification for Steel Sheet, Zinc-Aluminum-Magnesium Alloy-Coated by the Hot-Dip Process

B.2.7 American specifications on shear connectors

ASTM A29:2020	Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought
AWS D1.1:2020	Structural Welding Code-steel

B.3 Japanese specifications

The following Japanese specifications are published by the Japan Society of Civil Engineers, the Architectural Institute of Japan, Japanese Society of Steel Construction and the Japanese Standards Association, Tokyo, Japan.

B.3.1 Japanese specifications on design of steel structures

JASS 6: 2007	Structural Steelwork Specification for Building Construction

AIJ Design Standard for Steel Structures - Based on Allowable Stress Concept – (2005 Edition)

JSCE - Standard Specifications for Steel and Composite Structures(First Edition, 2009)

B.3.2 Japanese specifications on steel materials

JIS A 5523:2021	Weldable hot-rolled steel sheet piles
JIS A 5525:2019	Steel pipe piles
JIS A 5528:2021	Hot rolled steel sheet piles
JIS A 5530:2019	Steel pipe sheet piles
JIS G 3101:2020	Rolled steels for general structure
JIS G 3106:2020	Rolled steels for welded structure
JIS G 3114:2022	Hot-rolled atmospheric corrosion resisting steels for welded structure
JIS G 3128:2021	High yield strength steel plates for welded structure
JIS G 3131:2018	Hot-rolled mild steel plates, sheet and strip
JIS G 3132:2018	Hot-rolled carbon steel strip for pipes and tubes
JIS G 3136:2022	Rolled steels for building structure
JIS G 3302:2019	Hot-dip zinc-coated steel sheet and strip
JIS G 3312:2019	Prepainted hot-dip zinc-coated steel sheet and strip
JIS G 3321:2019	Hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip
JIS G 3322:2019	Prepainted hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip
JIS G 3350:2021	Light gauge sections for general structure
JIS G 3352:2014 (R 2019)	Steel decks
JIS G 3444:2021	Carbon steel tubes for general structure
JIS G 3466:2021	Carbon steel square and rectangular tubes for general structure
JIS G 3475:2021	Carbon steel tubes for building structure

B.3.3 Japanese specifications on dimensions and shapes

JIS G 3191:2022	Dimensions, mass, shape and permissible variations of hot rolled steel bars and bar in coil
JIS G 3192:2021	Dimensions, shape, mass and permissible variations of hot rolled steel sections
JIS G 3193:2019	Dimensions, shape, mass and permissible variations of hot rolled steel plates, sheets and strips
JIS G 3194:2020	Dimensions, shape, mass and permissible variations of hot rolled flat steel

B.3.4 Japanese specifications on bolting assemblies

Non-preloaded assemblies

JIS B 1051:2014 (R 2019)	Mechanical properties of fasteners made of carbon steel and alloy steel - Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread
JIS B 1052-2:2014	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread
JIS B 1180:2014 (R 2019)	Hexagon head bolts and hexagon head screws
JIS B 1181:2014 (R 2019)	Hexagon nuts and hexagon thin nuts
JIS B 1256:2008 (R2012)(R2017)	Plain washers

Preloaded assemblies

JIS B 1186:2013 (R2018)	Sets of high strength hexagon bolt, hexagon nut and plain washers for friction grip joints
JSS II-09:2015	Sets of torshear type high strength bolt, hexagon nut and plain washers for structural joints

B.3.5 Japanese specifications on welding consumables

JIS Z 3200:2005 (R2009)(R2014) (R2019)	Welding consumables – Technical delivery conditions for welding filler materials – Type of product, dimensions, tolerances and markings
JIS Z 3211:2008 (R2013)(R2018)	Covered electrodes for mild steel, high tensile strength steel and low temperature service steel
JIS Z 3313:2009 (R2013)(R2018)	Flux cored wires for gas shielded and self-shielded metal arc welding of mild steel, high strength steel and low temperature service steel

B.3.6 Japanese specifications on strips for cold-formed profiled sheetings

JIS G 3302:2019	Hot-dip zinc-coated steel sheet and strip
JIS G 3317:2019	Hot-dip zinc-5% aluminium alloy-coated steel sheet and strip
JIS G 3321:2019	Hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip

B.3.7 Japanese specifications on stud connectors

JIS B 1198:2011 (R2015)(R2020)	Headed studs

B.4 Australian/New Zealand specifications

The following Australian/New Zealand specifications are published by Standards Australia, Sydney, Australia; Standards New Zealand, Wellington, New Zealand.

B.4.1 Australian/New Zealand specifications on design of steel structures

AS 4100:2020	Steel structures
AS/NZS 4600: 2018	Cold-formed steel structures

B.4.2 Australian/New Zealand specifications on steel materials

AS/NZS 1163:2016	Cold-formed structural steel hollow sections
AS 1397:2021	Continuous hot-dip metallic coated steel sheet and strip - Coatings of zinc and zinc alloyed with aluminium and magnesium
AS 1548:2008	Fine grained, weldable steel plates for pressure equipment (Reconfirmed 2018)
AS/NZS 1594:2002	Hot-rolled steel flat products
AS/NZS 1595:1998	Cold-rolled, unalloyed, steel sheet and strip (Amendment 2014)
AS/NZS 3678:2016	Structural steel – hot-rolled plates, floor plates and slabs (Amendment 2017)
AS/NZS 3679.1:2016	Structural steel – Part 1: Hot-rolled bars and sections

B.4.3 Australian/New Zealand specifications on dimensions and shapes

AS/NZS 1365-1996	Tolerances for Flat-Rolled Steel Products (Amendment 2014)
AS 1548:2008	Fine grained, weldable steel plates for pressure equipment (Reconfirmed 2018)
AS/NZS 3679.1:2016	Structural steel – Part 1: Hot-rolled bars and sections

B.4.4 Australian/New Zealand specifications on bolting assemblies

AS 1110.1:2015	SO metric hexagon bolts and screws - Product grades A and B Screws
AS 1110.2:2015	ISO metric hexagon bolts and screws - Product grades A and B Bolts
AS 1111.1:2015	ISO metric hexagon bolts and screws - Product grade C Bolts
AS 1111.2:2015	ISO metric hexagon bolts and screws - Product grade C Screws
AS 1112.1:2015	ISO metric hexagon nuts Style 1 - Product grades A and B
AS 1112.2:2015	ISO metric hexagon nuts Style 2 - Product grades A and B
AS 1112.3:2015	ISO metric hexagon nuts Product grade C
AS 1112.4:2015	ISO metric hexagon nuts Chamfered thin nuts - Product grades A and B
AS 4291.1:2015	Mechanical properties of fasteners made of carbon steel and alloy steel Bolts, screws and studs

AS/NZS 1252.1:2016	High-strength steel fastener assemblies for structural engineering - Bolts, nuts and washers Part 1: Technical requirements
AS/NZS 1252.2:2016	High-strength steel fastener assemblies for structural engineering- Bolts, nuts and washers Part 2: Verification testing for bolt assemblies
AS/NZS 1559:1997	Hot-Dip Galvanized Steel Bolts and Associated Nuts and Washers for Tower Construction
AS/NZS 4291.2:2016	Mechanical properties of fasteners made of carbon steel and alloy steel Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread

B.4.5 Australian/New Zealand specifications on welding consumables

AS/NZS 1554.1:2014	Structural steel welding Part 1: Welding of steel structures (Amendment 2015 and 2017)
AS/NZS ISO 14171:2013	Welding consumables - Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels - Classification
AS/NZS ISO 14174:2013	Welding consumables - Fluxes for submerged arc welding and electroslag welding - Classification
AS/NZS 4855:2007	Welding consumables—Covered electrodes for manual metal arc welding of non-alloy and fine grain steels— Classification
AS/NZS 4857:2006	Welding consumables Covered electrodes for manual metal arc welding of high-strength steels Classification
AS/NZS 1167.2:1999	Welding and Brazing - Filler Metals Part 2: Filler Metal for Welding
AS/NZS 14341:2012	Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels – Classification (ISO 14341:2010, MOD)
AS/NZS 16834:2013	Welding consumables - Wire electrodes, wires, rods and deposits for gas shielded arc welding of high strength steels – Classification (ISO 16834:2012, MOD)
AS/NZS 21952:2012	Welding consumables - Wire electrodes, wires, rods and deposits for gas shielded arc welding of creep-resisting steels - Classification (ISO 21952:2012, MOD)

B.4.6 Australian/New Zealand specifications on strips for cold-formed profiled sheetings

AS 1397:2021	Continuous hot-dip metallic coated steel sheet and strip - Coatings of zinc and zinc alloyed with aluminium and magnesium

B.4.7 Australian/New Zealand specifications on stud connectors

AS/NZS 1554.2:2003	Structural steel welding Part 2: Stud welding (steel studs to steel) (Amendment 2003)

B.5 Chinese specifications

The following Chinese specifications are published by the Standardization Administration of China, Beijing, People's Republic of China.

B.5.1 Chinese specifications on design of steel structures

GB 50017:2017	Standard for design of steel structures
GB 50018:2002	Technical code of cold-formed thin-wall steel structures
GB 50661:2011	Code for welding of steel structure
JGJ 82:2011	Technical specification high strength bolt connections of steel structures
GB 50661:2011	Code for welding of steel structures

B.5.2 Chinese specifications on steel materials

GB/T 700:2006	Carbon structural steels
GB/T 1591:2018	High strength low alloy structural steels
GB/T 3274:2017	Hot-rolled plates and strips and strips of carbon structural steels and high strength low alloy structural steels
GB/T 4171:2008	Atmospheric corrosion resisting structural steel
GB/T 5313:2010	Steel plate with through-thickness characteristics
GB/T 6725:2017	General requirements of cold forming steel sections
GB/T 8162:2018	Seamless steel tubes for structural purposes
GB/T 13304.1:2008	Steels classification – Part 1: Classification of according to chemical composition
GB/T 13304.2:2008	Steels classification – Part 2: Classification of according to main quality classes and main property or application characteristics
GB/T 15574:2016	Steel products classification
GB/T 19879:2015	Steel plate for building structures
GB/T 20933:2021	Hot rolled sheet pile
YB 4104:2000	Steel plates for high rise building structure
GB/T 16270-2009	High strength structural steel plates in the quenched and tempered condition

B.5.3 Chinese specifications on dimensions and shapes

GB/T 702:2017	Hot-rolled steel bars – Dimensions, shape, weight and tolerances
GB/T 706:2016	Hot-rolled section steel
GB/T 709:2019	Dimension, shape, weight and tolerances for hot-rolled steel strip, plate and sheet
GB/T 6728:2017	Cold forming hollow sectional steel for general structure
GB/T 11263:2017	Hot-rolled H and cut T section steel
GB/T 17395:2008	Dimensions, shapes, masses, and tolerances of seamless steel tubes
GB/T 25052:2010	Continuously hot-dip coated steel sheet and strip -- Tolerances on dimensions, shape and weight

B.5.4 Chinese specifications on bolting assemblies

General information

GB/T 3098.1:2010	Mechanical properties of fasteners – Bolts, screws and studs
GB/T 3098.2:2015	Mechanical properties of fasteners – Nuts

Materials

GB/T 699:2015	Quality carbon structure steels
GB/T 3077:2015	Alloy structure steels
GB/T 6478:2015	Steels for cold heading and cold extruding

Non-preloaded assemblies

GB/T 41:2016	Hexagon nuts, style 1 – Product grade C
GB/T 95:2002	Plain washers – Product grade C
GB/T 5780:2016	Hexagon head bolts – Product grade C
GB/T 5781:2016	Hexagon head bolts – Full thread – Product grade C
GB/T 5782:2016	Hexagon head bolts
GB/T 5783:2016	Hexagon head bolts – Full thread
GB/T 6170:2015	Hexagon nuts, style 1
GB/T 6175:2016	Hexagon nuts, style 2

Preloaded assemblies

GB/T 1228:2006	High strength bolts with large hexagon head for steel structures
GB/T 1229:2006	High strength large hexagon nuts for steel structures
GB/T 1230:2006	High strength plain washers for steel structures
GB/T 1231:2006	Specifications of high strength bolts with large hexagon head, large hexagon nuts, plain washers for steel structures
GB/T 3632:2008	Sets of torshear type high strength bolt hexagon nut and plain washer for steel structures

B.5.5 Chinese specifications on welding consumables

GB/T 3429:2015	Wire rods for welding
GB/T 5117:2012	Covered electrodes for manual metal arc welding of non-alloy and fine grain steels
GB/T 5118:2012	Covered electrodes for manual metal arc welding of creep-resisting steels
GB/T 5293:2018	Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels
GB/T 8110:2020	Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels
GB/T 10045:2018	Tubular cored electrodes for non-alloy and fine grain steels
GB/T 12470:2018	Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of creep-resisting steels
GB/T 14957:1994	Steel wires for melt welding
GB/T 14981:2009	Dimension, shape, mass and tolerance for hot-rolled round wire rod
GB/T 17493:2018	Tubular cored electrodes for creep-resisting steels

B.5.6 Chinese specifications on strips for cold-formed profiled sheetings

GB/T 2518:2019	Continuously hot-dip zinc and zinc alloy coated steel sheet and strip
GB/T 12755:2008	Profiled steel sheet for building

B.5.7 Chinese specifications on stud connectors

GB/T 10433:2002	Cheese head studs for arc stud welding

B.6 Russian specifications

The following Russian standards are published by Russian Scientific-Technical Information Centre for Standardization, Metrology and Conformity Assessment, Moscow, Russian; Ministry of Regional Development of the Russian Federation, Moscow, Russian; Ministry of Construction, Housing and Utilities of the Russian Federation, Moscow, Russian.

B.6.1 Russian specifications on design of steel structures

SP 16.13330.2011	Steel Structures - the Updated Edition of SNiP II-23-81
SP 260.1325800.2016	Cold-formed thin-walled steel profile and galvanized corrugated plate constructions. Design rules
GOST 23118-2012	Building steel structures. General specifications

B.6.2 Russian specifications on steel materials

GOST 380-2005	Common quality carbon steel. Grades
GOST 535-2005	Common quality carbon steel bar and shaped sections. General specifications
GOST 1050-2013	Metal products from nonalloyed structural quality and special steels. General specification
GOST 1577-93	Rolled sheets and wide strips of structural quality steel. Specifications
GOST 2284-79	Cold-rolled carbon structural steel strip. Specifications
GOST 4543-71	Structural alloy steel bars. Specifications
GOST 4781-85	Hot-rolled steel shapes for sheet piles. Specifications
GOST 8731-74	Seamless hot-deformed steel pipes. Specifications
GOST 10705-80	Electrically welded steel tubes. Specifications
GOST 10706-76	Electrically welded steel line-weld tubes. Technical requirements
GOST 11268-76	Alloyed structural high-grade rolled steel sheets for special purposes. Specifications
GOST 11269-76	Alloyed universal structural high-grade rolled steel plates and wide strips for special purposes. Specifications
GOST 11474-76	Bent-steel sections. Specification
GOST 14637-89	Rolled plate from carbon steel of general quality. Specifications
GOST 19281-2014	High strength rolled steel. General specification
GOST 27772-2015	Rolled products for steel structural elements. General specifications
GOST 30245-2003	Steel bent closed welded square and rectangular section for building. Specification
GOST 53629-2009	Sheet piles of steel cold-formed sections. Specifications
GOST R 54864-2016	Hot-deformed seamless steel pipes for the welded steel structures. Specifications

B.6.3 Russian specifications on dimensions and shapes

GOST 103-2006	Hot-rolled steel strip. Dimensions
GOST 2590-2006	Round hot-rolled steel bars. Dimensions
GOST 2591-2006	Square hot-rolled steel bars. Dimensions
GOST 4781-85	Hot-rolled steel shapes for sheet piles. Specifications
GOST 7511-73	Steel sections for window and lantern transoms and window panels of industrial buildings. Specifications
GOST 8239-89	Hot-rolled steel flange beams. Rolling products
GOST 8240-97	Hot-rolled steel channels. Assortment
GOST 8278-83	Roll-formed steel channels. Dimensions
GOST 8281-80	Steel roll-formed unequal channels. Dimensions
GOST 8282-83	Bent-steel C-shaped equai flange sections. Dimensions
GOST 8283-93	Bent steel hat equal sections. Dimensions
GOST 8509-93	Hot-rolled steel equal-leg angles. Dimensions
GOST 8510-86	Hot-rolled steel unequal-leg angles. Dimensions
GOST 8732-78	Seamless hot-deformed steel pipes. Range of sizes
GOST 9576-75	Precision steel tubes. Range
GOST 10704-91	Electrically welded steel line-weld lubes. Range
GOST 13229-78	Steel bent Z-shaped sections. Dimensions
GOST 19771-93	Roll-formed steel equal leg angles. Dimensions
GOST 19772-93	Roll-formed steel unequal les angles. Dimensions
GOST 19903-2015	Hot-rolled steel sheets. Dimensions
GOST 19904-90	Cold-rolled steel sheets. Dimensions
GOST 26020-83	Hot-rolled steel I-beam with parallel flange edges. Dimensions
GOST 30245-2003	Steel bent closed welded square and rectangular section for building. Specifications
GOST 32528-2013	Hot-deformed seamless steel pipes. Specifications
GOST 53629-2009	Sheet piles of steel cold-formed sections. Specifications

B.6.4 Russian specifications on bolting assemblies

General information

GOST 1759.0-87	Bolts, screws, studs and nuts. Specifications
GOST 18123-82	Washers. General specifications
GOST 18126-94	Bolts and nuts with thread diameter over 48 mm. General specifications
GOST R 52643-2006	High-strength screws and nuts washers for metal structures. General specifications
GOST R ISO 898-1-2014	Mechanical properties of fasteners made of carbon and alloyed steels. Part 1: Bolts, screws and studs with specified property classes large and small thread pitch
GOST R ISO 898-2-2013	Mechanical properties of fasteners made of carbon and alloyed steels. Part 2: Nuts with specified property classes large and small thread pitch

Non-preloaded assemblies

GOST 6402-70	Lock washers. Specifications
GOST 7805-70	Hexagon bolts, product grade A. Construction and dimensions
GOST 7798-70	Hexagon bolts, product grade B. Construction and dimensions
GOST 10602-94	Hexagon head bolts with thread diameter over 48 mm. Product grade B. Specifications
GOST 10605-94	Hexagon nuts with thread diameter over 48 mm. Product grade B. Specifications
GOST 10906-78	Square taper washers. Specifications
GOST 11371-78	Washers. Specifications
GOST 11850-72	Steel wire for spring washers. Specifications
GOST ISO 4032-2014	Hexagon regular nuts (style 1). Product grades A and B
GOST ISO 8673-2014	Hexagon regular nuts (style 1) with fine pitch thread. Product grades A and B

Preloaded assemblies

GOST R 52644-2006	High-strength bolt with a hexagonal head with the increased size of turnkey metal structures. specifications
GOST R 52645-2006	Hexagon nuts for high-strength structural bolting with large width across flats. Specifications
GOST R 52646-2006	Washers for high-strength bolts metal structures. Specifications

B.6.5 Russian specifications on welding consumables

GOST 2246-70	Welding steel wire. Specifications
GOST 9087-81	Welding melted fluxes. Specifications
GOST 9467-75	Metal covered electrodes for manual arc welding of structural and heat-resistant steels. Types
GOST 26101-84	Welding powder wire. Specifications
GOST 26271-84	Flux-cored wire welding carbon and low-alloy steels. General specifications
GOST 5.1215-72	Metal arc welding electrodes of mark AHO-4 for mild structural steel. Quality requirements for certified products

B.6.6 Russian specifications on strips for cold-formed profiled steel sheetings

GOST 16523-97	Rolled sheets from quality and ordinary carbon steel for purposes. Specifications
GOST 17066-94	Rolled sheet of high-strength steel. Specifications
GOST 19903-2015	Hot-rolled steel sheets. Dimensions
GOST 19904-90	Cold-rolled steel sheets. Dimensions
GOST R 52246-2004	Hot-dip zinc-coated steel sheet. Specifications

B.6.7 Russian specifications on stud connectors

GOST 1759.0-87	Bolts, screws, studs and nuts. Specifications
GOST R ISO 898-1-2014	Mechanical properties of fasteners made of carbon and alloyed steels. Part 1: Bolts, screws and studs with specified property classes large and small thread pitch

Appendix C Quality control practices adopted by regulatory authorities

C.1 Quality control practice in Australia and New Zealand

C.2 Quality control practice in Hong Kong

C.3 Quality control practice in Macau

C.4 Quality control practice in Malaysia

C.5 Quality control practice in Singapore

Appendix C Quality control practice adopted by regulatory authorities

This Appendix provides brief descriptions of the quality assurance practices on the use of equivalent steel materials adopted by the following countries and cities:

a) Australia and New Zealand
b) Hong Kong,
c) Macau,
d) Malaysia, and
e) Singapore

It should be noted that full details of the operational procedures of these quality assurance systems may be found in the latest version of the local codes of practice and specifications.

C.1 Quality control practice in Australia and New Zealand

In Australia and New Zealand, structural engineers are the professionals responsible to ensure that civil and building structures as erected comply with AS 4100 and NZS 3404, and therefore comply with the Building Code of Australia and the New Zealand Building Code, respectively. They are required to issue a certificate indicating such compliance. The form of this certificate may be dictated by the Principal Certifying Authority or may be of a form decided by the certificate provider. The compliance involves the following steps:

(1) Ensuring that the materials used conform to those used in design, which means the materials comply with Section 2 'Materials' of AS 4100 and NZS 3404;

(2) Ensuring that the fabrication complies with Section 14 'Fabrication' of AS 4100 and NZS 3404;

(3) Ensuring that the erected structure complies with Section 15 'Erection' of AS 4100 and NZS 3404.

In general, the quality of steel materials should be controlled by the following means:

(a) In-line marking at the time of manufacture which allows the product to be inspected and its provenance checked;
(b) Test reports or certificates providing results from tests performed by a laboratory accredited by signatories to the ILAC (International Laboratory Accreditation Cooperation) Mutual Recognition Agreement (MRA) on behalf of the manufacturer, which allows the actual test values for a heat to be compared against the requirements of the relevant Standard. The appropriate logo or further details of the ILAC (MRA) signatory shall be noted on the document. [N.B. ILAC MRA accredited bodies include: in Australia, the National Association of Testing Authorities (NATA); and, in New Zealand, the International Accreditation New Zealand (IANZ)].

Mandatory information of the following test results include:

- Product, testing specification and grade, e.g. AS/NZS 3679.1—350 Grade
- Product steelmaking process, e.g. Basic oxygen—Slab cast
- Heat number (from casting).
- Mechanical properties—Tensile tests: Yield stress, tensile strength and percentage elongation.
- Chemical analysis type, e.g. cast analysis 'L' or product 'P'
- Chemical composition of Carbon (C), Phosphorus (P), Manganese (Mn), Silicon (Si), Sulphur (S), Chromium (Cr), Molybdenum (Mo), Vanadium (V), Nickel (Ni), Copper (Cu), Aluminium (Al), Titanium (Ti), Niobium (Nb), Carbon Equivalence Value (CEV) and any element intentionally added.

- Impact test results at the specified test temperature for low temperature and seismic grades (L0 and S0 Grades).

In addition, the Australasian Certification Authority for Reinforcing and Structural Steels (ACRS) is a not-for-profit third-party certification organization formed by industry and government associations on behalf the construction industry in 2000 (modelled on UK CARES). It aims to ensure manufacture and supply of construction steels to the industry can be independently and expertly demonstrated to meet the requirements of the relevant AS/NZS Standards. ACRS is accredited as a product certification body to ISO/IEC 17065. As well as the ACRS scheme, the Australian Technical Infrastructure Committee (ATIC), which is a government agency, has launched ATIC Scheme 10 through Joint Accreditation System of Australia and New Zealand (JAS-ANZ).

C.2 Quality control in Hong Kong

In Hong Kong, all responsibility to the structural safety of building structures rests upon Registered Structural Engineers, who are experienced structural engineers with dual registration recognized by the Hong Kong Institution of Engineers and the Buildings Department of the Government of Hong Kong SAR. The RSEs should exercise proper control of all structural safety issues in the design and construction of building structures together with proper quality control of all construction materials, including structural steel materials.

For each construction project, there is a designated RSE approved by the Buildings Department. The RSE or his representative should confirm the supply sources of the steel materials as well as the quality assurance systems effectively implemented during production of the steel materials. He is also responsible for endorsing the steel materials mill certificates while the steel manufacturers should issue an authenticated test certificate for every batch of the steel materials. Mandatory information on the following test results include:

- Yield strength
- Tensile strength
- Elongation limit
- Impact energy
- Chemical contents, based on a ladle or a product analysis, of Carbon (C), Sulphur (S), Phosphorous (P), Silicon (Si), Manganese (Mn), Copper (Cu), Chromium (Cr), Molybdenum (Mo), Nickel (Ni), Aluminium (Al), Niobium (Nb), Titanium (Ti), Vanadium (V), Nitrogen (N) and any other element intentionally added.
- The value of CEV.
- Hardness for bolts, nuts and washers.

It should be noted that the RSE may request additional material tests on samples of steel materials selected in fabrication plants or on construction sites.

All the material testing should be carried out by accredited laboratories recognized by the Hong Kong Laboratory Accreditation Scheme (HOKLAS) or their mutually recognized laboratories. The scope of the material testing required is similar to those listed in Item a) above.

It should be noted that HOKLAS is an accreditation scheme operated by the Hong Kong Accreditation Service (HKAS) under the management of the Innovation and Technology Commission, the Government of Hong Kong SAR. The scheme is open to the voluntary participation of any Hong Kong laboratory which performs objective testing and calibration falling within the scope of the Scheme and meets the HOKLAS criteria of competence.

For further information on the use of equivalent steel materials and associated quality control procedures for construction projects in Hong Kong, please refer to the Code of Practice for the Structural Use of Steel.

C.3 Quality control in Macau

In Macau, structural engineers are responsible for all structural safety issues in the design and construction of building structures together with good quality control for all construction materials, including structural steel materials.

For structural steel works, structural engineers are required to ensure that all steel materials are in compliance with the requirements specified in the Code of Structural Steel for Buildings (REAE) (2001) which was prepared with the cooperation of the Land, Public Works and Transport Bureau (DSSOPT) of the Government of Macao SAR and the Civil Engineering Laboratory of Macau (LECM). Quality control activities should be carried out by contractors according to REAE, as well as to the Approval & Reception Procedure (ARP) (prepared by the quality assurance entities nominated by the Government of Macau SAR) for public projects.

DSSOPT is one of the public organizations under the Government of Macau SAR providing technical support and giving suggestions for policy making related to physical developments in the areas of land management and utilization, urban planning, infrastructure, and basic services in Macau. The Bureau also defines guidelines for economic and societal developments as well as other activities of the interest of Macau.

LECM is a non-profit making technical and scientific organization acting in the public interest with technical, budgetary and patrimonial autonomy. It provides technical support in the areas of civil engineering and related sciences to the Government of Macau SAR, and also to civil engineering construction firms undertaking both public and private works in Macau.

Steel manufacturers should issue an authenticated mill certificate for every batch of steel materials, and mandatory information on the following test results including:

- Geometrical properties
- Mechanical Properties : Yield strength, Tensile strength, Elongation limit
- Impact energy
- Chemical contents, based on a ladle or a product analysis, of Carbon (C), Sulphur (S), Phosphorous (P), Silicon (Si), Manganese (Mn), Copper (Cu), Chromium (Cr), Molybdenum (Mo), Nickel (Ni), Aluminium (Al), Niobium (Nb), Titanium (Ti), Vanadium (V), Nitrogen (N), CEV and any other element intentionally added.
- Mechanical properties and hardness for bolts, nuts and washers

Structural engineers may request additional material tests on samples of steel materials selected in fabrication plants and on construction sites.

For further information on the use of equivalent steel materials and associated quality control procedures for construction projects in Macau, please refer to the Code of Structural Steel for Buildings (REAE).

C.4 Quality control in Malaysia

In Malaysia, construction practice closely follows the European Standards. The design of steel structures, steel-concrete composite structures adopts the Structural Eurocodes EN 1993 and EN 1994, with their own National Annex. Structural engineers are responsible for ensuring that civil and building structures as erected comply with the standards, and therefore comply with the Malaysia Standards or Uniform Building by Law.

The Construction Industry Development Board of Malaysia (CIDB) was established under the Construction Industry Development Board Act entrusted with the responsibility of coordinating the needs and wants of the Construction Industry.

The CIDB is also responsible for endorsing the construction materials and products with a 'Certificate of Approval'. Hence, the structural steel products and other building materials should comply with the Malaysian Industrial Standard for local applications. Mandatory information on the following test results required for the 'Certificate of Approval' include:

- Yield strength
- Tensile strength
- Elongation limit
- Impact energy
- Chemical contents, based on a ladle or a product analysis, of Carbon (C), Sulphur (S), Phosphorous (P), Silicon (Si), Manganese (Mn), Copper (Cu), Chromium (Cr), Molybdenum (Mo), Nickel (Ni), Aluminium (Al), Niobium (Nb), Titanium (Ti), Vanadium (V), Nitrogen (N) and any other element intentionally added.
- The value of CEV
- Hardness for bolts, nuts and washers.

For further information regarding the 'Certificate of Approval' and associated quality control procedures for construction projects in Malaysia, please refer to the website: http://www.cidb.gov.my .

C.5 Quality control in Singapore

In Singapore, the Building and Construction Authority is the regulatory authority which is responsible for safe design and construction of buildings as well as quality control of all constructional materials, including steel materials. In general, Qualified Persons (QPs) should specify and design with only those steel materials manufactured by steel manufacturers with a valid Factory Production Certificate in full accordance with the steel materials specifications adopted in the design stage. It should be noted that the Factory Production Certificate should be issued by a certification agency acceptable to Building and Construction Authority. For the list of acceptable certification agencies, please refer to BC1: 2012.

Moreover, the steel manufacturers should also issue an authenticated test certificate for every batch of steel materials, and mandatory information on the following test results include:

- Yield strength
- Tensile strength
- Elongation limit
- Impact energy
- Chemical contents, based on a ladle or a product analysis, of Carbon (C), Sulphur (S), Phosphorous (P), Silicon (Si), Manganese (Mn), Copper (Cu), Chromium (Cr), Molybdenum (Mo), Nickel (Ni), Aluminium (Al), Niobium (Nb), Titanium (Ti), Vanadium (V), Nitrogen (N) and any other element intentionally added.
- The value of CEV.
- Hardness for bolts, nuts and washers.

For further information on the use of equivalent steel materials and associated quality control procedures for construction projects in Singapore, please refer to the Design Guide on Use of Alternative Structural Steel to BS5950 and Eurocode 3 (BC1).

Appendix D Worked Examples

D.1 Acceptance of British/European steel materials

D.2 Acceptance of American steel materials

D.3 Acceptance of Japanese steel materials

D.4 Acceptance of Australian/New Zealand steel materials

D.5 Acceptance of Chinese steel materials

D.6 Acceptance of Russian steel materials

D.7 Acceptance of Class E3 steel materials

D.1 Acceptance of British/European steel materials

Consider a batch of Grade S355J0 steel plates have been received in a construction site in Hong Kong. A site engineer of this construction site received the corresponding mill certificate of the steel plates as illustrated in Figure D1.

British Steel – Mill Test Certificate

Order Number: 1006XX-XXXXXXX

Certificate Number: 1006XX-100-XXXXX

Date of Issue: 10 June 20XX

PO Number: 4XXXXXXX

Supplier: Tata Steel, Shotton, U.K.

Customer: CNERC for Steel Construction

Commodity: PLATE

Specification: EN10025-2 S355J0

Sample

Size	Product No	Quantities	Heat No.	Position	Tensile test Ys Ts E_L (N/mm^2) (%)	Impact test Energy (J)	Chemical compositions (%) C $x10^{-4}$	Si $x10^{-3}$	Mn $x10^{-3}$	P $x10^{-4}$	S $x10^{-4}$	CEV $x10^{-3}$
10 x 2400 x 6000	PA61XXX	2	SA4XX	T	416 584 31	1: 129 2: 114 3: 121 4: 121	1613	347	1436	180	45	408

- Position - T: Top. M: Middle B: Bottom
- Tensile test. Direction: Transverse; Gauge length = $5.65\sqrt{A_0}$ (Rectangular)
- Impact test. Direction: 1/4T Longitudinal ; Sub-size 10mm x 7.5mm
  T.L.R. (Trans Longitude Ratio)
- Division – 1. Ladle analysis
- Supply Condition: As-Rolled unless otherwise Heat Treated

We hereby certify that the material herein has been made in accordance with the order and above specification. This material has been fully killed and made by basic oxygen process.

This material has been made by vacuum degreasing process. This material is fine grained steel.

*This Mill Test Certificate cannot be copied for any purpose.

CE

THIS CERTIFICATE IS DISTRIBUTED BY ISO9001 : 2008 CERT. NO. HKG 0953579

Figure D1 Mill certificate of Grade S355JO steels

Comparison against requirements of chemical compositions: (Table MR1)

i) Carbon content : $C_{steel} = 0.1613 \le C_{HK} = 0.26$ Ok

ii) Phosphorus content : $P_{steel} = 0.0180 \le P_{HK} = 0.045$

iii) Sulphur content : $S_{steel} = 0.0045 \le S_{HK} = 0.050$

iv) CEV : $CEV_{steel} = 0.408 \le CEV_{HK} = 0.49$

Comparison against requirements of mechanical properties: (Table 4.2a & MR1)

i) Yield strength : $R_{e,steel} = 416 \ge R_{e,HK} = 355$ Ok

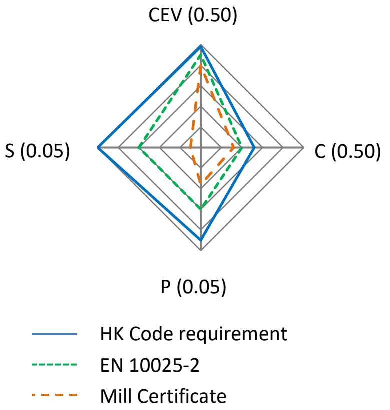
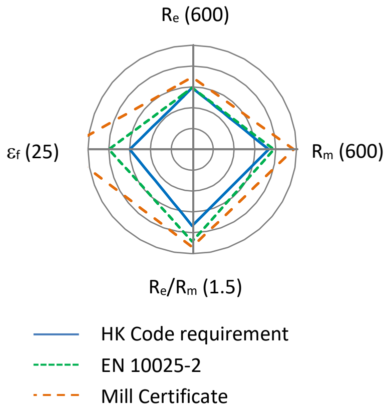
ii) Tensile strength : $R_{m,steel} = 584 \ge R_{m,HK} = 440$

iii) Elongation limit : $\varepsilon_{f,steel} = 31 \ge \varepsilon_{f,HK} = 15$

iv) Strength ratio : $R_{m,steel}/R_{e,steel} = 1.40 \ge R_{m,HK}/R_{e,HK} = 1.10$

v) Impact toughness : $KV_{steel} = 114J@0^oC \ge KV_{HK} = 27J@0^oC$

Table D1 Key information for selection of equivalent steel materials

National material specification	Chemical composition (%)				Mechanical properties			
	C	P	S	CEV	R_e (N/mm^2)	R_m (N/mm^2)	ε_f (%)	R_m/R_e
HK Code requirement	0.26	0.045	0.050	0.49	355	440	15	≥1.10
EN 10025-2	0.20	0.030	0.030	0.45	355	470	22	1.32
Mill Certificate of 10mm thick S355J0 steel plate	0.16	0.018	0.005	0.41	416	584	31	1.40
Comparisons against key parameters								

Based on the values listed in the mill certificate, all the requirements of chemical compositions and mechanical properties are found to be satisfied. Thus, the steel materials should be accepted.

The steel mill has obtained a **CE** mark for their steel products. Hence, both the manufacturing process and the quality control system have been demonstrated in the mill certificate to have an effective implementation of a certified **Factory Production Control** system (refer to Section 3.4.1).

Consequently, as outlined in Section 3.2.2, the steel materials are classified as **Class E1** structural steels, and the material class factor γ_{MC} is taken as 1.0 (see Table 3.1). According to Table 4.2a, the minimum yield strength R_{eH} is specified as 355N/mm^2, while the tensile strength R_m is specified as 440N/mm^2. Hence, the nominal values of yield strength f_y and tensile strength f_u should be equal to R_{eH} and R_m respectively.

D.2 Acceptance of American steel materials

Consider a batch of Grade 55 steel plates received in a construction site in Hong Kong. A site engineer of this construction site received the corresponding mill certificate of the steel plates as illustrated in Figure D2.

American Steel

Certified Mill Test Report

Certificate Number: 881903-100-XXXXX
Date of issue: 12 May 20XX

Steel product: Hot rolled / Steel Plate
Specification: ASTM A572 Grade 55
Customer: CNERC for Steel Construction
Supply Condition: As Rolled, Killed

Sample

Chemical composition

Product Number	Plate Number	Heat No.	Dimensions (mm)			QTY (PCS)	Chemical ladle analysis (%)							
			T	W	L		C	Si	Mn	P	S	Cu	Ni	CEV
1002F-31XXX	BXXXXX	SA4XX	20	1574	6056	8	0.12	0.31	1.50	0.03	0.03	0.3	0.3	0.44

Mechanical properties

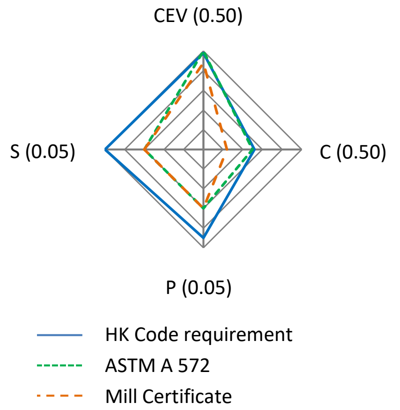
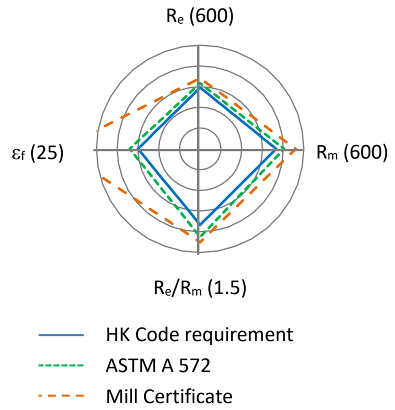
Product Number	Plate Number	Heat No.	Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	ε_f (%)	Impact toughness
1002F-31XXX	BXXXXX	SA4XX	409	553	34	96J at 20°C

We hereby certify that the material herein has been made in accordance with the order and above specification. This material has been fully killed and made by basic oxygen process.

This material has been made by vacuum degreasing process. This material is fine grained steel.

Figure D2 Mill certificate of Grade 55 steels

Table D2 Key information for selection of equivalent steel materials

National material specification	Chemical composition (%)				Mechanical properties			
	C	P	S	CEV	R_e (N/mm^2)	R_m (N/mm^2)	ε_f (%)	R_m/R_e
HK Code requirement	0.26	0.045	0.050	0.49	355	440	15	≥1.10
ASTM A572	0.25	0.030	0.030	0.50*	380	485	17	1.28
Mill Certificate of 20mm thick Grade 55 steel plate	0.12	0.030	0.030	0.44	409	553	34	1.35
Comparisons against key parameters								

Note: * it can be specified by the purchaser.

Comparison against requirements of chemical compositions: (Table MR1)

i) Carbon content : C_{steel} = 0.12 ≤ C_{HK} = 0.26 Ok
ii) Phosphorus content : P_{steel} = 0.030 ≤ P_{HK} = 0.045
iii) Sulphur content : S_{steel} = 0.030 ≤ S_{HK} = 0.050
i) CEV : CEV_{steel} = 0.44 ≤ CEV_{HK}= 0.49

Comparison against requirements of mechanical properties: (Table 4.2a & MR1)

i) Yield strength : $R_{e,steel}$ = 409 ≥ $R_{e,HK}$ = 355 Ok
ii) Tensile strength : $R_{m,steel}$ = 553 ≥ $R_{m,HK}$ = 440
iii) Elongation limit : $\varepsilon_{f,steel}$ = 34 ≥ $\varepsilon_{f,HK}$ = 15
iv) Strength ratio : $R_{m,steel}/R_{e,steel}$ = 1.35 ≥ $R_{m,HK}/R_{e,HK}$ = 1.10
v) Impact toughness : KV_{steel} = 96J@20°C ≥ KV_{HK} = 27J@20°C

Based on the values listed in the mill certificate, all the requirements of chemical compositions and mechanical properties are found to be satisfied. Thus, the steel materials should be accepted.

The steel mill has obtained an **ISO 9001** mark for factory quality management system, but no certified **Factory Production Control** system is demonstrated in the mill certificate. Hence, the manufacturing process and quality control system is considered to have in-house quality assurance system but not a certified **Factory Production Control** system (refer to Section 3.4.1).

Consequently, as outlined in Section 3.2.2, the steel materials provided are classified as **Class E2** structural steels, and the material class factor γ_{MC} is taken as 1.1 (see Table 3.1). Hence, the strengths of the equivalent Grade 55 steel plates are calculated as follows:

Minimum yield strength (R_{eH}) and ultimate tensile strength (R_m): (Table 4.8)

For 20mm thick plate : $R_{eH} = 0.95R_{eH0} = 361N/mm^2$ $R_m = 0.95R_{m0} = 461N/mm^2$

Design values of yield strength (f_y) and ultimate tensile strength (f_u): (Equation 3.1 & 3.2)

For 20mm thick plate : $f_y = 361/1.1 = 328N/mm^2$ $f_u = 461/1.1 = 419N/mm^2$

D.3 Acceptance of Japanese steel materials

Consider a batch of Grade SYW295 sheet piles received in a construction site in Hong Kong. A site engineer of this construction site received the corresponding mill certificate of the steel piles as illustrated in Figure D3.

Japanese Steel **Mill Test Certificate** **Sample**

CERTIFICATE No.: JS-20XX-800-XXXXX DATE OF ISSUE: Feb 24, 20XX

CONTRACT No.: NIS3620XX-XX CLIENT: CNERC for Steel Construction

PRODUCT: Steel Sheet Pile / Hot Rolled SPECIFICATION: JIS A 5523

Chemical composition

Product No.	Heat No.	Steel Grade	Dimensions	Quantity	Chemical composition of the ladle analysis (%)							
			T*W*L (mm^3)	(PCS)	C	Si	Mn	P	S	Cu	Ni	CEV
JS20XX-25XX	JS7XX	SYW295	25*1523*8061	5	0.15	0.31	1.46	0.03	0.03	0.3	0.3	0.43

Mechanical properties

Product No.	Quantity (PCS)	Mechanical properties			
		Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	ε_f (%)	Impact toughness
JS20XX-25XX	5	395	521	32	126J at 20°C

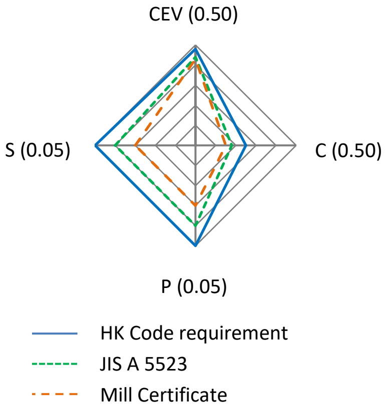
ADDITIONAL DETAIL
- ✓ This material has been fully killed.
- ✓ We hereby certify that the material described herein has been manufactured, sampled and tested by XXXXX Steel & Metal Inc., in accordance with the above specification and the client order requirements. All results meet the corresponding requirements.
- ✓ In product certification system covered by JQA, JIS No. A5528 is for Hot Rolled Steel Sheet Piles.

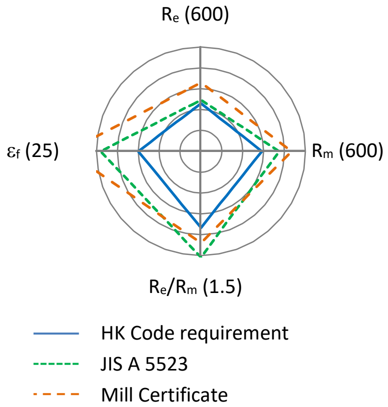
Figure D3 Mill certificate of Grade SYW295 steels

Table D3 Key information for selection of equivalent steel materials

National material specification	Chemical composition (%)				Mechanical properties			
	C	P	S	CEV	R_e (N/mm^2)	R_m (N/mm^2)	ε_f (%)	R_m/R_e
HK Code requirement	0.25	0.050	0.050	0.48	275	350	15	≥1.10
JIS A 5523	0.18	0.040	0.040	0.44	295	450	24	1.53
Mill Certificate of 25mm thick Grade SYW295 steel sheet pile	0.15	0.030	0.030	0.43	395	521	32	1.32

Comparisons against key parameters





Comparison against requirements of chemical compositions: (Table MR4)

i) Carbon content : C_{steel} = 0.15 ≤ C_{HK} = 0.25 Ok
ii) Phosphorus content : P_{steel} = 0.03 ≤ P_{HK} = 0.05
iii) Sulphur content : S_{steel} = 0.03 ≤ S_{HK} = 0.05
iv) CEV : CEV_{steel} = 0.43 ≤ CEV_{HK} = 0.48

Comparison against requirements of mechanical properties: (Table 4.2a & MR4)

i) Yield strength : $R_{e,steel}$ = 395 ≥ R_e = 275 Ok
ii) Tensile strength : $R_{m,steel}$ = 521 ≥ R_m = 350
iii) Elongation limit : $\varepsilon_{f,steel}$ = 32 ≥ ε_f = 15
iv) Strength ratio : $R_{m,steel}/R_{e,steel}$ = 1.32 ≥ R_m/R_e = 1.10
v) Impact toughness : KV_{steel} = 126J@20°C ≥ KV_{HK} = Nil

Based on the values listed in the mill certificate, all the requirements of chemical compositions and mechanical properties are found to be satisfied. Thus, the steel materials should be accepted.

The steel mill has obtained a **JIS** mark for their steel products. Hence, both the manufacturing process and the quality control system have been demonstrated in the mill certificate to have an effective implementation of a certified **Factory Production Control** system (refer to Section 3.4.1).

Consequently, as outlined in Section 3.2.2, the steel materials provided are classified as **Class E1** structural steels, and the material class factor γ_{MC} is taken as 1.0 (see Table 3.1). According to Table 4.2c, the yield strength and tensile strength of Grade SYW295 steel sheet piles should be taken as R_{eH} = 295 N/mm^2 and R_m = 450 N/mm^2 respectively. Hence, the design yield strength f_y is specified as R_{eH}/1.0 = 295N/mm^2, while the design tensile strength f_u is specified as R_m/1.0 = 450N/mm^2.

D.4 Acceptance of Australian/New Zealand steel materials

Consider a batch of Grade 350 steel plates received in a construction site in Hong Kong. A site engineer of this construction site received the corresponding mill certificate of the steel plates as illustrated in Figure D4.

TEST CERTIFICATE

Sample

AUSTRALIAN STEEL

Page 1of 1
Certificate No.: 561XXX
Transmission Date: XX/XX/20XX

Customer:	CNERC FOR STEEL CONSTRUCTION HONG KONG, CHINA	Supplier:	XXXXXXX STEEL LTD N.S.W., AUSTRALIA.
		Sales Order No:	809XXX
		Printed at:	Supplier XXXXX
Cust. Order No.:	0370 XXXX XXXX	Printed on:	XX/XX/20XX

STEELMAKING: Basic Oxygen- Slab Cast
SPECIFICATION: **AS/NZS 3678 – 350**
PRODUCT: **PLATE**

Item No	Heat No	Dimensions (mm)	Units	Mass (Tonnes)
2432	3897306	2400.0x12x6000	5	6.780
2432	3897308	2400.0x12x6000	20	20.340

I certify that the original records of the company show that the item(s) referred to on this certificate conform to the specification as stated.

Approved Signatory
Mechanical LAB 051

Approved Signatory
Chemical LAB 052

CHEMICAL ANANLYSIS

Percentage of element by mass *L/P = Cast / Product; CF = Chemical Formula*

Item No	Heat / Unit No	Lab No	L/P	C	P	Mn	Si	S	Ni	Cr	Mo	V	Cu	Al-T	CF1
2432	3897306	052	L	.165	.012	.71	.16	.012	.009	.012	.003	<.003	.012	.042	.29
2432	3897308	052	L	.153	.022	.65	.15	.014	.007	.018	<.002	<.003	.008	.035	.27

CF1 = C + (Mn/6) + (Cr+Mo+V)/5 + (Cu+Ni)/15

MECHANICAL TESTS

Tensile AS 1391 *(Loc = Test Piece Location, TQF = Transverse Quarter Front End, CAT = Test Category, B=Batch)*

Item No	Heat / Unit No	Tested Unit	Lab No	Cat	Loc	Thick mm	ReH MPa	Rm MPa	Lo	ELONGN	IMPACT TOU.
2432	3897306	FD334	051	B	TQF	12.0	480	530	A	26	84J@20℃
2432	3897308	FD336	051	B	TQF	12.0	420	480	A	27	86J@20℃

For gauge length (Lo), A=5.65 *square root of the original cross-sectional area of the test piece.

COMMENTS

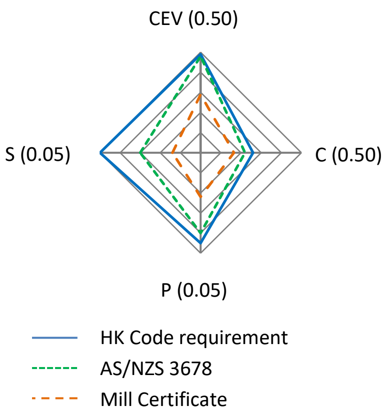
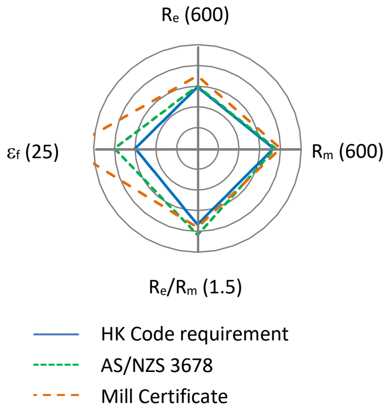
THIS PRODUCT IS SUPPLIED IN ACCORDANCE WITH THE REQUIREMENTS OF AS/NZS 3678:2016 SAMPLING AND CHEMICAL ANALYSIS ARE PERFORMED IN ACCORDANCE WITH BLUESCOPE STEEL PROCEDURE DH-LABS-QS-00 S05.07C. MECHANICAL TESTING HAS BEEN PERFORMED ON SAMPLES SUPPLIED BY THE RELEVANT PRODUCTION DEPARTMENTS. HEAT TREATMENT- PRODUCT AS ROLLED.

ACRS
ABN: 40 XXX XXX XXX

JAS-ANZ

Figure D4 Mill certificate of Grade 350 steels

Table D4 Key information for selection of equivalent steel materials

National material specification	Chemical composition (%)				Mechanical properties			
	C	P	S	CEV	R_e (N/mm^2)	R_m (N/mm^2)	ε_f (%)	R_m/R_e
HK Code requirement	0.26	0.045	0.050	0.49	355	440	15	≥1.10
AS/NZS 3678	0.22	0.040	0.030	0.48	360	450	20	1.25
Mill Certificate of 12mm thick Grade 350 steel plate	0.165	0.022	0.014	0.29	420	480	26	1.14
Comparisons against key parameters								

Comparison against requirements of chemical compositions: (Table MR1)

i) Carbon content : C_{Steel} = 0.165 ≤ C_{HK} = 0.26 Ok
ii) Phosphorus content : P_{Steel} = 0.022 ≤ P_{HK} = 0.045
iii) Sulphur content : S_{Steel} = 0.014 ≤ S_{HK} = 0.050
iv) CEV : CEV_{Steel} = 0.29 ≤ CEV_{HK} = 0.49

Comparison against requirements of mechanical properties: (Table 4.2a & MR1)

i) Yield strength : $R_{e,steel}$ = 420 ≥ R_e = 355 Ok
ii) Tensile strength : $R_{m,steel}$ = 480 ≥ R_m = 440
iii) Elongation limit : $\varepsilon_{f,steel}$ = 26 ≥ ε_f = 15
iv) Strength ratio : $R_{m,steel}/R_{e,steel}$ = 1.14 ≥ R_m/R_e = 1.10
v) Impact toughness : KV_{steel} = 84J@20°C ≥ KV_{HK} = 27J@20°C

Based on the values listed in the mill certificate, all the requirements of chemical compositions and mechanical properties are found to be satisfied. Thus, the steel materials should be accepted.

The steel mill has obtained an **ACRS** mark for their steel products. Hence, both the manufacturing process and the quality control system have been demonstrated in the mill certificate to have an effective implementation of a certified **Factory Production Control** system (refer to Section 3.4.1).

Consequently, as outlined in Section 3.2.2, the steel materials provided are classified as **Class E1** structural steels, and the material class factor γ_{MC} is taken as 1.0 (see Table 3.1). According to Table 4.2d, the yield strength and tensile strength of Grade 350 steel sheet piles should be taken as R_{eH} = 350 N/mm^2 and R_m = 430 N/mm^2 respectively. Hence, the design yield strength f_y is specified as R_{eH}/1.0 = 350N/mm^2, while the design tensile strength f_u is specified as R_m/1.0 = 430N/mm^2.

D.5 Acceptance of Chinese steel materials

Consider a batch of Grade Q235B steel strips received in a construction site in Hong Kong. A site engineer of this construction site received the corresponding mill certificate of the steel strips as illustrated in Figure D5.

XXXX IRON & STEEL CO., LTD **CHINESE STEEL**

INSPECTION CERTIFICATE **Sample**

Manufacturer: CORE BASE

CUSTOMER	CNERC for Steel Construction	PRODUCT	Hot-rolled strip, Carbon steel		
PURCHASER	CNERC for Steel Construction	CUTOMER'S NO.	000XXX	CERTIFICATE NO.	BGSAXXXXXX0170
SPECIFICATION	GB/T 3274 GB/T 700	CUTROMER ORDER NO.			
		DATE OF ISSUE	20XX/05/28		
STEEL GRADE	Q235B	LICENSE NO.		MILL'S NO.	Q2EXXXX3328

NO.	COIL/PACK NO.	QTY	Heat No.	MATERIAL DESCRIPTION			CHEMICAL COMPOSITION %					
				THICK	WIDTH	LENGTH	C	Si	Mn	P	S	CEV
				mm			$x10^2$	$x10^2$	$x10^2$	$x10^3$	$x10^3$	$x10^2$
1	378XXXX27	4	SA4X27	25	1000	COIL	16	17	57	35	19	33
2	378XXXX28	3	SA4X27	25	1500	COIL	16	17	57	35	19	33
3	378XXXX51	9	SAXX34	14	1500	COIL	17	19	43	21	19	31
4	378XXXX52	6	SA4X36	14	1500	COIL	18	21	43	20	15	32

NO.	MECHANICAL PROPERTIES							
	TENSILE TEST			IMPACT TEST				BENDING TEST
	Y. S.	T. S.	EL	KCV				180°
	MPa		%	°C	J			Qualified
1	295	456	28	20	96	93	87	Qualified
2	301	465	29	20	84	69	78	Qualified
3	297	480	29	20	95	84	71	Qualified
4	309	484	26	20	78	86	72	Qualified

REMARKS		
NOTES	Y.S. = YIELD STRENGTH T.S = TENSILE STRENGTH EL = ELONGATION G.L. = GAUGE LENGTH L1 = 5.65 SQRT(FO)	
SURVEYOR TO	WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED HEREIN HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH THE ORDER REQUIREMENTS OF THE ABOVE MATERIAL SPECIFICATION.	*Signature* QULITY MANAGER

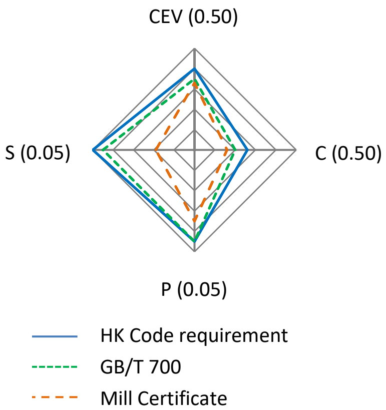
TESTING
CNAS L5287

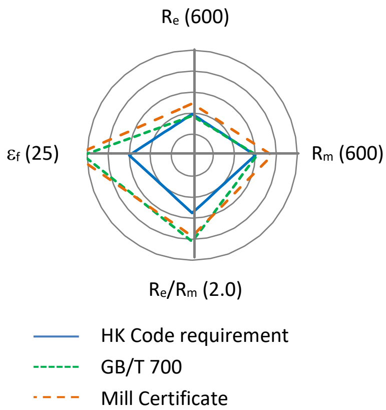
Figure D5 Mill certificate of Grade Q235B steels

Table D5 Key information for selection of equivalent steel materials

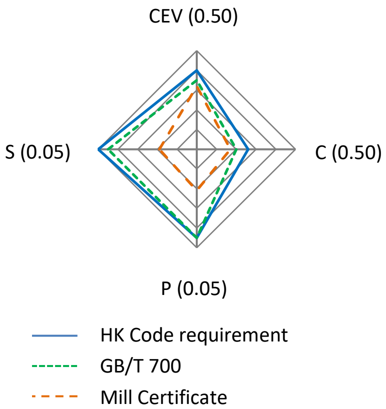
National material specification	Chemical composition (%)				Mechanical properties			
	C	P	S	CEV	R_e (N/mm^2)	R_m (N/mm^2)	ε_f (%)	R_m/R_e
HK Code requirement	0.26	0.045	0.050	0.40	235 (225)	360	15	≥1.10
GB/T 700	0.20	0.045	0.045	0.35	235 (225)	370	26 (25)	1.64 (1.68)
Mill Certificate of 25mm thick Grade Q235B steel plate	0.16	0.035	0.019	0.33	295	456	28	1.55
Mill Certificate of 14mm thick Grade Q235B steel plate	0.18	0.021	0.019	0.32	297	480	26	1.62

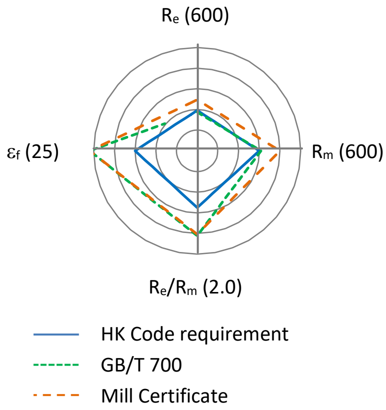
Comparisons against key parameters for 25mm thick Grade Q235B steel plate





Comparisons against key parameters for 14mm thick Grade Q235 steel plate





Note: the data in bracket is for thickness t (mm): 16 < t ≤ 40.

For 25mm thick Grade Q235B steel plate:

Comparison against requirements of chemical compositions: (Table MR1)

i) Carbon content : C_{steel} = 0.16 ≤ C_{HK} = 0.26 Ok
ii) Phosphorus content : P_{steel} = 0.035 ≤ P_{HK} = 0.045
iii) Sulphur content : S_{steel} = 0.019 ≤ S_{HK} = 0.050
iv) CEV : CEV_{steel} = 0.33 ≤ CEV_{HK} = 0.40

Comparison against requirements of mechanical properties: (Table 4.2a & MR1)

i) Yield strength	: $R_{e,steel}$	= 295	≥ $R_{e,HK}$	= 2225	Ok
ii) Tensile strength	: $R_{m,steel}$	= 456	≥ $R_{m,HK}$	= 360	
iii) Elongation limit	: $\varepsilon_{f,steel}$	= 28	≥ $\varepsilon_{f,HK}$	= 15	
iv) Strength ratio	: $R_{m,steel}/R_{e,steel}$	= 1.55	≥ $R_{m,HK}/R_{e,HK}$	= 1.10	
v) Impact toughness	: KV_{steel}	= 69J@20°C	≥ KV_{HK}	=27J@20°C	

For 14mm thick Grade Q235B steel plate:

Comparison against requirements of chemical compositions: (Table MR1)

iv) Carbon content	: S_{teel}	= 0.18	≤ C_{HK}	= 0.26	Ok
v) Phosphorus content	: P_{steel}	= 0.021	≤ P_{HK}	= 0.045	
vi) Sulphur content	: S_{steel}	= 0.019	≤ S_{HK}	= 0.050	
v) CEV	: CEV_{steel}	= 0.32	≤ CEV_{HK}	= 0.40	

Comparison against requirements of mechanical properties: (Table 4.2a & MR1)

vi) Yield strength	: $R_{e,steel}$	= 297	≥ $R_{e,HK}$	= 235	Ok
vii) Tensile strength	: $R_{m,steel}$	= 480	≥ $R_{m,HK}$	= 360	
viii) Elongation limit	: $\varepsilon_{f,steel}$	= 26	≥ $\varepsilon_{f,HK}$	= 15	
ix) Strength ratio	: $R_{m,steel}/R_{e,steel}$	= 1.62	≥ $R_{m,HK}/R_{e,HK}$	= 1.10	
x) Impact toughness	: KV_{steel}	= 71J@20°C	≥ KV_{HK}	= 27 J@20°C	

Based on the values listed in the mill certificate, all the requirements of chemical compositions and mechanical properties are found to be satisfied. Thus, the steel materials should be accepted.

The steel mill has obtained a **CQC** (i.e., ISO 9001) mark for factory quality management system, but no certified **Factory Production Control** system is demonstrated in the mill certificate. Hence, the manufacturing process and quality control system is considered to have in-house quality assurance system but not a certified **Factory Production Control** system (refer to Section 3.4.1).

Consequently, as outlined in Section 3.2.2, the steel materials provided are classified as **Class E2** structural steels, and the material class factor γ_{MC} is taken as 1.1 (see Table 3.1). Hence, the strengths of the equivalent Grade Q235B steel plates are calculated as follows:

Minimum yield strength (R_{eH}) and ultimate tensile strength (R_m): (Table 4.8)

i) For 14mm thick plate: $R_{eH} = R_{eH0} = 235$ N/mm^2 $R_m = R_{m0} = 370$ N/mm^2

ii) For 25mm thick plate: $R_{eH} = 0.95R_{eH0} = 214$ N/mm^2 $R_m = 0.95R_{m0} = 351$ N/mm^2

Nominal values of yield strength (f_y) and ultimate tensile strength (f_u): (Equation 3.1 & 3.2)

i) For 14mm thick plate: $f_y = 235/1.1 = 214$ N/mm^2 $f_u = 370/1.1 = 336$ N/mm^2

ii) For 25mm thick plate: $f_y = 214/1.1 = 194$ N/mm^2 $f_u = 351/1.1 = 319$ N/mm^2

D.6 Acceptance of Russian steel materials

Consider a batch of C355 steel sections received in a construction site in Hong Kong. A site engineer of this construction site received the corresponding mill certificate of the steel sections as illustrated in Figure D6.

Russian Steel, Inc.

Structural and Rail Division, Mosco, Russia

ISO 9001 and GOSSTROY Certified

Sample

CERTIFIED MILL TEST REPORT

Ship to:
CNERC for steel construction
HONG KONG, CHINA

Bill to:
CNERC for steel construction
HONG KONG, CHINA

GENERAL INFORMATION

Product	Wide Flange Beam
Size	35Ш3
Heat Number	AXXX092
Condition	As Rolled
	Fine Grained
	Fully Killed
	No Weld Repair

SPECIFICATIONS

Standards	**Grades**
ГОСТ 26020	
ГОСТ 27772	C355

SHIPMENT DETAILS

Bol # 0000XXXX – 5380kg

Bundle
0602XXXX03

Length
18m

Pcs
4

CHEMICAL ANANLYSIS (weight percent)

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	Al	Ti	C1
.08	1.24	.015	.024	.22	.27	.08	.09	.029	.033	<.001	.005	.005	.33

* Carbon equivalent C1 = C + (Mn/6) + (Cr+Mo+V)/5 + (Cu+Ni)/15

MECHANICAL TESTING

Test	Yield strength σ_T, MPa	Tensile strength σ_B, MPa	σ_B / σ_T ratio	Elongation δ, %	**Charpy Impact Tests**				
					Temp. °C	KCV, J			
						Specimen 1	Specimen 2	Specimen 3	Average
1	386	506	1.31	25	-40	113	86	125	108
2	390	508	1.30	25	-40	101	133	98	111

I hereby certify that this material described herein has been made to the applicable specification by the electric arc furnace / continuous cast process and tested in accordance with the requirements of the material specification and applicable purchaser designated requirements.

Signed: ______________________________

Manager of Product Quality and Process Improvement

CERTIFICATIONS

ДОБРОВОЛЬНАЯ РСТ СЕРТИФИКАЦИЯ

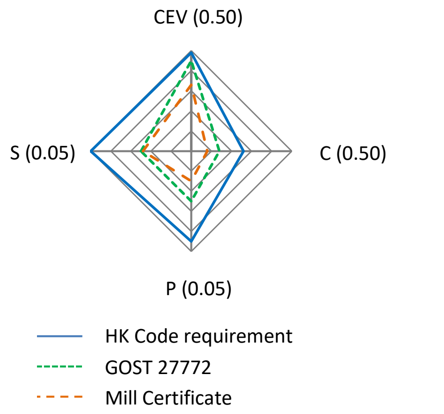
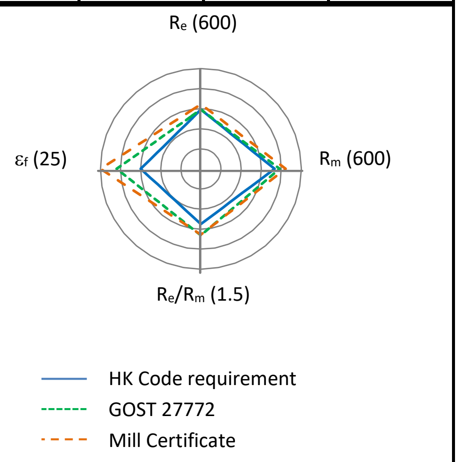
СИСТЕМА МЕНЕДЖМЕНТА СЕРТИФИЦИРОВАНА ИСО 9001

Certificate of the GOSSTROY

Russian Register ISO 9001

Figure D6 Mill certificate of Grade C355 section steels

Table D6 Key information for selection of equivalent steel materials

National material specification	Chemical composition (%)				Mechanical properties			
	C	P	S	CEV	R_e (N/mm^2)	R_m (N/mm^2)	ε_f (%)	R_m/R_e
HK Code requirement	0.26	0.045	0.050	0.49	355	440	15	≥1.10
GOST 27772	0.14	0.025	0.025	0.45	355	470	21	1.32
Mill Certificate of 15mm thick Grade C355 steel plate for 35Ш3 section	0.08	0.015	0.024	0.33	386	506	25	1.31
Comparisons against key parameters								

Comparison against requirements of chemical compositions: (Table MR1)

i) Carbon content : C_{Steel} = 0.08 ≤ C_{HK} = 0.26 Ok
ii) Phosphorus content : P_{Steel} = 0.015 ≤ P_{HK} = 0.045
iii) Sulphur content : S_{Steel} = 0.024 ≤ S_{HK} = 0.050
iv) CEV : CEV_{Steel} = 0.33 ≤ CEV_{HK} = 0.49

Comparison against requirements of mechanical properties: (Table 4.2a & MR1)

vi) Yield strength : $R_{e,steel}$ = 386 ≥ R_e = 355 Ok
vii) Tensile strength : $R_{m,steel}$ = 506 ≥ R_m = 440
viii) Elongation limit : $\varepsilon_{f,steel}$ = 25 ≥ ε_f = 15
ix) Strength ratio : $R_{m,steel}/R_{e,steel}$ = 1.31 ≥ R_m/R_e = 1.10
x) Impact toughness : KV_{steel} = 86J@-40°C ≥ KV_{HK} = 27J@-40°C

Based on the values listed in the mill certificate, all the requirements of chemical compositions and mechanical properties are found to be satisfied. Thus, the steel materials should be accepted.

The steel mill has obtained a **GOSSTROY** mark for their steel products. Hence, both the manufacturing process and the quality control system have been demonstrated in the mill certificate to have an effective implementation of a certified **Factory Production Control** system (refer to Section 3.4.1).

Consequently, as outlined in Section 3.2.2, the steel materials provided are classified as **Class E1** structural steels, and the material class factor γ_{MC} is taken as 1.0 (see Table 3.1). According to Table 4.2f, the yield strength and tensile strength of Grade C355 steel sections should be taken as R_{eH} = 355 N/mm^2 and R_m = 470 N/mm^2 respectively. Hence, the design yield strength f_y is specified as R_{eH}/1.0 = 355N/mm^2, while the design tensile strength f_u is specified as R_m/1.0 = 470N/mm^2.

D.7 Acceptance of Class E3 steel materials steel materials

Consider a batch of steel plates have been left unused in a construction site in Hong Kong, and the corresponding mill certificate of the steel plates was missing. In another case, there is a variety of structural steel mixed together, but the mill certificates can't be confirmed for every kind of steel by the site engineer of this construction site.

Due to the lack of certified values of chemical compositions and mechanical properties, these steels cannot be demonstrated to be manufactured in accordance with the requirements of any acceptable materials specifications or quality assurance system.

Consequently, as outlined in Section 3.2.2, the steel materials provided are classified as **Class E3** structural steel, and there is no need to specify any material tests. The yield strength of the steel should be conservatively limited to 170 N/mm^2 for structural design or other constructional uses. For example, they can be used as temporary enclosure structure in the construction site.

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

国家钢结构工程技术研究中心
National Engineering Technology Research Center for Steel Construction

國家鋼結構工程技術研究中心香港分中心
Chinese National Engineering Research Centre
For Steel Construction (Hong Kong Branch)

Selection of Equivalent Steel Materials to European Steel Materials Specifications

Professional Guide: PG-003

Second Edition

HONG KONG CMSA
Constructional Metal Structures Association
香港建築金屬結構協會

中国钢铁工业协会

CONSTRUCTION INDUSTRY COUNCIL
建造業議會