PART SEVEN
CISC CODE OF STANDARD PRACTICE AND MISCELLANEOUS DATA

CISC

CODE OF STANDARD PRACTICE

for Structural Steel

Eighth Edition

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TABLE OF CONTENTS

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for Structural Steel

PREFACE

The CISC Code of Standard Practice for Structural Steel is a compilation of usual industry practices relating to the design, fabrication and erection of structural steel. These practices evolve over a period of time and are subject to change as improved methods replace those of an earlier period. The Code is revised whenever a sufficient number of changes have occurred to warrant a new edition.

The first edition of the Code was adopted and published in November 1958. A second edition incorporating minor revisions was published in October 1962. The third edition, published in September 1967 and revised in May 1970, incorporated minor changes throughout with principal changes in Section 2 - Definition of Structural Steel and Section 3 - Computation of Weights for Unit Price Bids.

The fourth edition adopted in June 1980, revised December 1980, broadened the scope to include bridges and other structures. It also incorporated the CISC "Guide to Tendering Procedures" into Section 3 and Appendices B and C. The Code was converted to SI (metric) units and provided conversion factors and Imperial units in Appendix E.

The fifth edition (1991) reflected the steel standard's recognition of the preparation of five types of fabrication and erection documents which may be produced in fulfilling a steel construction contract. These documents may be in the form of drawings, diagrams, sketches, computer output, hand calculations and other data which can be supplied by the fabricator/erector. This data is generally referred to in contract documents as "shop drawings". The computation of mass has been changed by deleting the mass of welds and the allowances for paint and other coatings. Appendix B, Guideline for Unit Price Application for Changes, and Appendix C, A Suggested Format for Price-Per-Unit of Mass or Price-Per-Item Contracts were substantially revised. To foster uniformity, two new appendices were added: Miscellaneous Steel and A Suggested Format for a Monthly Progress Claim Form.

The sixth edition (1999) clarified the role of the fabricator, the information required, and where that information is expected, as stipulated in the governing technical standards. Added were: definitions of Design Drawings and Quotations, clauses on quotations, discrepancies, shims for bearing surfaces, the allowance for return of documents, the information required when painting is specified, and Appendix H - Suggested Definitions for Progress Invoicing and Substantial Performance. Changes were also made to Appendix C, the terminology for Unit Price contracts, connection types, and anchor rods – the latter two to be consistent with the changes in CSA Standard CAN/CSA-S16-01.

The seventh edition (2008) added two new appendices: I - Architecturally Exposed Structural Steel (AESS) and J - Digital Modelling, in order to give guidance to designers, owners, and contractors on these two important topics. As each of these topics involved issues that vary widely and approaches differ, the Code endeavoured to identify and clarify the main points that should be addressed by the interested parties to avoid conflicts during actual construction. In addition, definitions of AESS, Steel Detailer and Work, and a time frame for accepting erected steelwork were added.

This eighth edition (2015) was updated by a consensus of stakeholders within the Canadian steel construction industry. Committee members included steel fabricators, erectors, detailers,

engineers, architects and general contractors. The Code underwent major revisions reflecting this consensus approach with noted changes including BIM (electronic documents), temporary bracing, conditions where lintels would be included in a steel contract, computations of units and mass, and erection stability.

Whenever a gender-specific term is used, it shall be read as gender-neutral.

By documenting standard practices, the CISC Code of Standard Practice aims to provide guidance on current practices in the Canadian structural steel fabrication and erection industry and its clients.

The latest edition of the Code can be found on the CISC website (*www.cisc-icca.ca*).

Canadian Institute of Steel Construction

Adopted September 23, 2015

1. General Provisions

1.1 Scope

This Code covers standard industry practice with respect to the furnishing of structural steel, joist, and platework, in the absence of provisions to the contrary contained in the Contract.

1.2 Definitions

Architect	As defined under the appropriate provincial Architect's Act.
Architecturally Exposed Structural Steel	Structural steel which is specifically designated as architecturally exposed and the appearance of which is governed by Appendix I, Architecturally Exposed Structural Steel.
BIM Administrator	The BIM Administrator is responsible from the pre-design phase onwards to develop and to track the object-oriented BIM against predicted and measured performance objectives, supporting multi-disciplinary building information models that drive analysis, schedules, take-off and logistics.
BIM Execution Plan	The document that defines the expected BIM deliverables and guides the coordination of the project teams. (Includes the BIM Responsibility Matrix).
Building Information Model (BIM)	A digital representation of the physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life-cycle – defined as existing from earliest conception to demolition. Note: the term Digital/Electronic Model may be used in lieu of the term BIM in some sectors.
Client	A person, corporation, or authority with whom the Fabricator and/or Erector have contracted.
Change Directive	A written instruction signed by the General Contractor directing the Fabricator and/or Erector to proceed with a change in the Work within the general scope of the Contract Documents, prior to the General Contractor and the Fabricator and/or Erector agreeing upon adjustments in the contracted price and the contracted time.
Change Order	A written amendment to the Subcontract signed by the Contractor and the Subcontractor stating their agreement upon: ▪ A change in the Subcontract Work ▪ The method of adjustment or the amount of the adjustment in the Subcontract price, if any, and ▪ The extent of the adjustment in the Subcontract time, if any.

Connection Design Details	Documents which provide details of standard and non-standard connections and other data necessary for the preparation of shop details.
Construction Documents	The most recent of IFC drawings, specifications, computer output, models and electronic/digital data used to govern the construction of the Works.
Construction Specifications	The IFC Specifications used to govern the construction of the Works.
Contract	The undertaking by the parties to perform their respective duties, responsibilities and obligations as prescribed in the Contract Documents; represents the entire agreement between the parties.
Contract Documents	Include the Construction Documents and all commercial terms and conditions governing the Work (including schedule).
Cost-Plus Contract	An Agreement whereby the Fabricator and/or Erector agrees to fulfill the contract for a consideration which is calculated on the basis of the Fabricator's and/or Erector's costs plus a specified fee as defined in the contract.
Design Documents	Drawings and specifications, including computer models, electronic documents and other data, as prepared by the Engineer of Record, showing member sizes and dimensions and all required forces for connection design, i.e. shears, axial forces, moments and torsions. (Refer to the governing technical standard for the entire list of mandatory requirements.)
Engineer	As defined under the appropriate provincial Professional Engineer's Act.
Engineer of Record	The Professional Engineer that assumes responsibility for the design. (Note: terminology of this individual varies from province to province depending on the local Engineering Act.)
Erection Bracing	Bracing materials or members which are used to plumb, align and stabilize structural members or the structure during construction and are removed when the structural members or the structure is secured by bolting or welding of structural members (not to be confused with Temporary Bracing).
Erection Diagrams	General arrangement drawings and/or models showing all information necessary for the assembly of the steel structure.

Erection Procedures	Outline the construction methods, erection sequence, erection and temporary bracing requirements, and other engineering details necessary for shipping, handling, erecting, and maintaining the stability of the structural steel frame.
Erector	The party responsible for erection of the steelwork.
Fabrication and Erection Documents	A collection of documents (hard copy, electronic and/or models) prepared by the Fabricator and/or Erector related to steel fabrication and erection.
Fabricator	The party responsible for furnishing the Structural Steel.
Field Work Details	Details that provide complete information for modifying fabricated members – both new and existing – in the field.
General Contractor, Constructor or Construction Manager	The person or corporation that constructs, coordinates, and supervises the construction of the Work.
General Terminology e.g. Beams, Joists, Columns, etc.	These terms have the meanings stated or implied in CSA-S16 (latest edition), CSA-S6 (latest edition) and Appendix A of this Code.
Industry Foundation Class Model	A platform-neutral, open-file format specification that is not controlled by a single vendor or group of vendors. It is an object-based file format with a data model developed by building SMART (formerly the International Alliance for Interoperability, IAI) to facilitate interoperability in the architecture, engineering and construction (AEC) industry, and is a commonly used collaboration format in Building information modelling (BIM) based projects. The Industry Foundation Class model specification is open and available. It is registered by ISO and is an official International Standard ISO 16739:2013.
Issued-for-Construction Documents (IFC)	The initial milestone set of drawings, specifications and other documents (including hard copy, electronic and/or models) produced by the Engineer of Record to be used by the Contractor, Fabricator and/or Erector and other trades for construction. Issued-for-Construction Documents shall conform to the requirements of CSA S16 or CSA S6.

Level of Development (LOD)	A specification that enables practitioners in the AEC Industry to specify and articulate with a high level of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process.
Lump Sum Price Contract	Also called Stipulated Price Contract; an agreement whereby the Fabricator and/or Erector contracts to fulfill the Contract terms for a lump sum (stipulated price) consideration.
Manufacturing Model	A 3D model created from the LOD that represents the "as fabricated" or "as shop issued" status. The manufacturing model is typically prepared by the detailer and should include all material in the accurate sizes, locations and profiles to represent what is fabricated in the assembled state, including bolts but not necessarily welds.
Miscellaneous Steel	Steel items described and listed in Appendix F of this Code.
Others	A party or parties other than the Fabricator and/or Erector.
Owner	The Owner of a structure, and shall include his authorized agent and any person taking possession of a structure on the Owner's behalf. Depending on the circumstances, an authorized agent may be the architect, engineer, general contractor, construction manager, public authority or other designated representative of the Owner.
Quotations	Proposals by the Fabricator based on Structural Steel as defined in Clause 2.1 and as included in the Tender Documents, and in accordance with the documents outlined in Clause 3.1.1.
Revision	A change in the Contract Documents.
Shop Details	Documents which provide complete information for the fabrication of various members and components of the structure, including the required material and product standards; the location, type, and size of all mechanical fasteners; bolt installation requirements and welds.
Steel Detailer	Those responsible for the preparation of shop details and other data necessary for fabrication and/or erection. May also be the Fabricator.

Steel Erection Execution Plan	Processes and procedures for the safe positioning, aligning and securing of the structural steel components on prepared foundations to form a complete frame.
Stipulated Price Contract	See Lump Sum Price Contract.
Structural Design Documents	May include drawings, specifications, computer output, and electronic and other data. The Structural Design Documents shall show a complete design of the structure with members suitably designated and located, including such dimensions and details as necessary to permit the preparation of Fabrication and Erection Documents. Documents shall be in accordance with CSA S16 and CSA S6.
Structural Steel	Those items listed under Clause 2.1
Structural Steel Frame	An assemblage of Structural Steel components (beams, columns, purlins, girts, etc.) for the purpose of resisting loads and forces. See Clause 2.1.
Structural Steel Specifications	The portion of the Tender Specifications containing the requirements for the fabrication and erection of the Structural Steel.
Temporary Bracing	Members that are designed by the Engineer of Record or a third party, to be removed at a later date at their instruction (not to be confused with Erection Bracing).
Tender Documents	Drawings, BIM files, specifications, general conditions, addenda, etc., used as the basis for preparing a tender.
Tender Drawings	Drawings used as the basis for preparing a tender.
Tender Specifications	Specifications used as the basis for preparing a tender.
Unit-Price Contract	Also called Price-per-Unit Contract. An agreement whereby the Fabricator and/or Erector contracts to fulfill the contract terms for a consideration which is based on the units of steel calculated in accordance with the CISC Code of Standard Practice for Structural Steel.
Work	The product and/or services provided by the Steel Fabricator and/or Erector.

1.3 Governing Technical Standards

The provisions of the latest edition of CSA-S16 "Limits States Design of Steel Structures" shall govern the design, fabrication and erection of steel structures except bridges. The provisions of the latest edition of CSA-S6 "Canadian Highway Bridge Design Code", the "Ontario Highway Bridge Design Code" (in Ontario) or the American Railway Engineering Association's "Specifications for Steel Railway Bridges" shall govern the design, fabrication and erection of structural steel for bridges. The provisions of the latest edition of CSA Standard W59 "Welded Steel Construction (Metal-Arc Welding)" shall govern arc welding design and practice. The provisions of other standards shall be applicable if called for in the Tender Drawings and Tender Specifications.

1.4 Responsibility for Design

When the Client provides the structural drawings and specifications, the Fabricator and the Erector shall not be responsible for determining the adequacy of the design nor be liable for the loss or damage resulting from an inadequate design. Should the Client desire the fabricator to assume any responsibility for design beyond that of proposing adequate connections and details, and, when required, components, members, or assemblies standardized by the Fabricator, the Client shall state clearly his requirements in the invitation to tender or in the accompanying Tender Drawings and Tender Specifications. Even though proposed connections and design details may be prepared by the Fabricator's technical staff, the overall behaviour of the structure remains the responsibility of the designer of the structure. (See also Clause 5.6).

1.5 Responsibility for Erection Procedure

When the erection of Structural Steel is part of his Contract, the Fabricator shall be responsible for determining the Erection Procedure, for checking the adequacy of the connections for the uncompleted structure, and for providing Erection Bracing or connection details. When the erection of the Structural Steel is not part of his Contract, the Fabricator shall not be responsible for determining the Erection Procedure, for checking the adequacy of the connections for the uncompleted structure, or for providing Erection Bracing or connection details not included in the Structural Design Documents, nor shall the Fabricator be liable for loss or damage resulting from faulty erection. However, the steel Fabricator shall be informed by the Client of the erection sequence to be used, which may influence the sequence and process of the manufacturing. (See also Clauses 5.1 and 5.4).

1.6 Patented Devices

Except when the Contract Documents call for the design to be furnished by the Fabricator and/or Erector, the Fabricator and/or Erector assume that all necessary patent rights have been obtained by the Client and that the Fabricator and/or Erector will be fully protected by the Client in the use of patented designs, devices or parts required by the Structural Design Documents.

1.7 Scheduling

The Client should provide a construction schedule in the Tender Documents. In the absence of such a schedule, one should be mutually agreed upon between the contracting parties, prior to the Contract award.

2. Classification of Material

2.1 Structural Steel

Unless otherwise specified in the Tender Documents, a Contract to supply, fabricate and deliver Structural Steel shall include only those items from the following list which are clearly indicated as being required by the Structural Design Documents. (See Appendix A)

2.1.1

Anchors for Structural Steel.

Base plates and bearings for Structural Steel members.

Beams, purlins, girts forming part of the Structural Steel frame.

Bearing plates and angles for Structural Steel members and steel deck.

Bins and hoppers of 6 mm plate or heavier, attached to the Structural Steel frame(s).

Bracing for Structural Steel members, steel trusses or steel frames.

Brackets attached to the Structural Steel.

Bridge bearings connected to the Structural Steel members.

Cables for permanent bracing or suspension systems.

Canopy framing if attached to the Structural Steel frame.

Cold-formed channels when used as structural members as listed in the CISC Handbook of Steel Construction.

Columns.

Conveyor galleries and supporting bents (exclusive of conveyor stringers, deck plate and supporting posts which are normally part of the conveyor assembly).

Crane rails and stops, excluding final alignment of the rails, unless otherwise noted on the Drawings.

Curb angles and plates attached to the Structural Steel frame where shown on the Structural Design Documents.

Deck support angles at columns, walls, where shown on the Structural Steel drawings.

Diaphragms for bridges.

Door frame supports attached to the Structural Steel frame.

Expansion joints connected to the Structural Steel frame (excluding expansion joints for bridges).

Field bolts to connect Structural Steel components.

Floor plates, roof plates (raised pattern or plain) and steel grating connected to the Structural Steel frame.

Girders.

Grillage beams of Structural Steel.

Hangers supporting Structural Steel framing.

Jacking girders.

Lintels shown, detailed and dimensioned on the Structural Design Documents.

Mechanical roof support and floor opening framing shown on Structural Design Documents.

Monorail beams of standard Structural Steel shapes.

Open-web steel joists, including anchors, bridging, headers and trimmers; also, when specified to be included in the Structural Steel Design Documents, light-gauge forms and temperature reinforcement.

Sash angles shown, detailed and dimensioned on the Structural Design Documents.

Separators, angles, tees, clips and other detail fittings essential to the Structural Steel frame.

Shear connectors/studs, except when installed through the sheet steel floor or roof deck by the deck installer.

Shelf angles shown, detailed and dimensioned on the Structural Design Documents.

Shop fasteners or welds, and fasteners required to assemble parts for shipment.

Steel connection plates or fixtures for Structural Steel embedded or anchored on site in concrete or masonry.

Steel tubes or cores for composite columns or braces.

Steel window sills attached to the Structural Steel frame.

Struts.

Suspended ceiling supports of Structural Steel shapes where shown on the Structural Design Documents.

Temporary components to facilitate transportation to the site.

Tie, hanger and sag rods forming part of the Structural Steel frame.

Trusses.

2.1.2 Only if shown and designed on the Structural Design Documents and specifically noted by the Tender Documents to be supplied by the Structural Fabricator:

Steel stairs, walkways, ladders and handrails forming part of the structural steelwork. (See Appendix A)

2.2 Field Connection Material

2.2.1 When the erection of the Structural Steel is part of the Fabricator's Contract, he shall supply all material required for temporary and for permanent connection of the component parts of the Structural Steel.

2.2.2 When the erection of the Structural Steel is not part of the Fabricator's Contract, unless otherwise specified in the Tender Documents, the Fabricator shall furnish appropriate bolts and nuts (plus washers, if required) or special fasteners, of suitable size and in sufficient quantity for all field connections of steel to steel which are specified to be thus permanently connected, plus an over-allowance of two per cent of each size to cover waste.

Unless otherwise specified in the Tender Documents, welding electrodes, back-up bars, temporary shims, levelling plates, fitting-up bolts and drift pins required for the Structural Steel shall not be furnished by the Fabricator when the erection of the Structural Steel is not part of the Fabricator's Contract.

2.3 Items Supplied by Others

Unless otherwise specified in the Tender Documents, the following steel or other items shall not be supplied by the Structural Steel Fabricator.

Bins and hoppers not covered in Clause 2.1 of this Code.

Bolts for wood lagging.
Bridge bearings not connected to Structural Steel items.
Canopy framing not attached to Structural Steel.
Catch basin frames.
Concrete for filling HSS or pipe sections. Concrete is to be supplied and poured by others in the shop or field with the cooperation of the Fabricator and/or Erector.
Connection material for other trades.
Conveyor stringers, deck plate and supporting posts.
Door and corner guards.
Door frames not covered in Clause 2.1 of this Code.
Drain pipes.
Drilling of holes into masonry or concrete, including core drilling of anchor rods for bridges and drilling for deck support angles.
Edge forming less than 3.2 mm thick for steel deck and not covered in Clause 2.1 of this code.
Embedded steel parts in precast concrete.
Embedded steel parts not required for Structural Steel or steel deck.
Flagpoles and supports.
Floor plates, roof plates and grating not covered in Clause 2.1 of this Code.
Grout.
Hoppers and chutes.
Hose and tire storage brackets.
Installation of structural steel parts embedded in concrete or masonry.
Lag bolts, machine bolts and shields or inserts for attaching any non-Structural Steel item
Lintels not shown, detailed and dimensioned on the Structural Design Documents.
Lintels which are an integral part of door frames.
Machine bases, rollers and pulleys.
Members made from gauge material except cold-formed channels indicated in Clause 2.1.
Metal-clad doors and frames.
Miscellaneous Steel; see Appendix F.
Shear connectors through sheet steel deck by deck installer.
Sheet steel cladding.
Sheet steel deck.
Sheet steel flashing.
Shelf angles not shown, detailed and dimensioned on the Structural Design Documents.
Shoring under composite floors and stub girders.
Steel doors.
Steel sash angles not shown, detailed and dimensioned on the Structural Design Documents.
Steel stacks.
Steel stairs, landings, walkways, ladders and handrails, not covered in Clause 2.1.2 of this Code.

Steel tanks and pressure vessels.

Steel window sills not covered in Clause 2.1 of this Code.

Support for sheet steel deck at column cut-outs and for openings not requiring framing, connected to Structural Steel.

Temporary bracing for other trades.

Trench covers.

Trim angles, eave angles or fascia plates not directly attached to the structural steel frame.

2.4 Custom Items

The responsibility for the supply and/or installation of items not conforming to the above lists shall be clearly identified by the Client at the time of tender.

3. Quotations and Contracts

3.1 Standard Form of Contract

Unless otherwise agreed upon, a Contract to fabricate, deliver and/or erect Structural Steel shall be the appropriate unaltered Standard Construction Document contract issued and duly sealed by the Canadian Construction Association (CCA) as listed at *www.cca-acc.com*.

3.1.1 Quotations

Unless otherwise stated, Quotations from Fabricators and/or Erectors are based on the following documents:

(1) The appropriate unaltered CCA Contract Document with copyright seal with no additional conditions, as issued by the Canadian Documents Committee.

It is accepted that alterations and/or additions to the standard CCA Contract Document by the General Contractor, Constructor or Construction Manager after Quotation may have implications not originally anticipated by the Fabricator and/or Erector. The use of non-standard Contracts, altered or modified CCA Contract Documents shall allow the Fabricator and/or Erector to incorporate related costs and implications into a new Quotation for consideration.

(2) Canadian Institute of Steel Construction (CISC) Code of Standard Practice for Structural Steel, latest edition.

3.1.2 Progress Payment Claim Form

A suggested format for a progress payment claim form is provided in Appendix G.

3.1.3 Progress Invoicing and Substantial Completion

For suggested recommended progress invoicing terms and definitions, see Appendix H.

3.2 Types of Contracts

3.2.1 For Lump Sum Price Contracts stipulating a "lump sum price", the work required to be performed by the Fabricator and/or Erector must be completely defined by the Tender Documents.

3.2.2 For Unit-Price Contracts stipulating a "price per unit", the scope of the Work, type of materials, character of fabrication, and conditions of erection are based upon the Tender Documents which must be a representative sample of the Work to be performed. Final unit

rates may be subject to adjustment, based on the complexity of the Issued-for-Construction (IFC) Documents. For methods of computing mass, area, or quantity, see Clause 3.5. Also see Appendix C of this Code for a suggested unit rate catalogue.

3.2.3 For Cost-Plus Contracts stipulating "cost plus fee", the Work required to be performed by the Fabricator and/or Erector is indefinite in nature at the time the Tender Documents are prepared. Consequently the Contract Documents should define the method of measurement of Work performed, and the fee to be paid in addition to the Fabricator's and/or Erector's costs.

3.3 Revisions to Contract Documents

3.3.1 Revisions to the Contract Documents shall be made by the issue of dated new or revised documents. All Revisions shall be clearly indicated. Such Revisions should be issued by a Change Notice. Revisions to the Work shall not be noted on Shop Details submitted for review but should be issued on revised Construction Documents.

3.3.2 The Fabricator and/or Erector shall advise the Client or Client's representative of any impact that such Revision or change will have on the price and/or schedule of the existing Contract. The response to the Change Notice shall be accompanied by a description of the impact change in sufficient detail to permit evaluation and prompt approval by the Client.

3.3.3 Upon agreement between the Fabricator and/or Erector and the Client or Client's representative as to the Revision's impact, the Client or his representative shall issue a Change Order or Extra Work Order for the Revision to the Contract for the change in the Work.

3.3.4 Unless specifically stated to the contrary, the issue of revised Contract Documents or Revisions indicated on the review documents is not authorization by the Client to release these Revisions for construction. Upon receipt of revised Construction Documents, the Fabricator and/or Erector shall notify the Client that a Revision to the Contract scope has been received, and a time frame shall be agreed for the Fabricator and/or Erector to advise the cost and schedule impact that the Revision will have on the Contract. Upon mutual agreement, and the Client's acceptance of the cost and schedule impact, the Fabricator and/or Erector will proceed with the Revision to the Work.

3.4 Discrepancies

Unless otherwise stated in the Construction Documents, the Structural Design Documents and Construction Specifications for buildings, the Construction Specifications govern. For bridges, the Structural Design Documents govern over Construction Specifications. In case of discrepancies between the Structural Design Documents and Design Documents for other trades or disciplines, the Structural Design Documents shall govern. When it has been agreed to use an electronic Building Information Model (BIM) as part of the Construction Documents, the BIM model shall govern for dimensions and geometry, while drawings shall govern for section sizes.

3.5 Computation of Units and Mass

Unless another method is specified and fully described at the time Tenders are requested, the computed mass of steel required for the structure shall be determined by the method of computation described herein. (Although the method of computation described does not result in the actual mass of fabricated Structural Steel and other items, its relative simplicity results in low computational cost and is based on quantities which can be readily computed and checked by all parties involved to establish the basis of payment). No additional mass for welds

or mass allowance for painting, galvanizing, and metallizing is to be included in the computation of mass.

a) *Mass Density.* The mass density of steel is assumed to be 7850 kilograms per cubic metre.

b) *Shapes, Bars and Hollow Structural Sections.* The mass of shapes, bars and hollow structural sections is computed using the finished dimensions shown on shop details. No deductions shall be made for holes created by cutting, punching or drilling, for material removed by coping or clipping, or for material removed by weld joint preparation. No cutting, milling or planning allowance shall be added to the finished dimensions. The mass per metre of length for shapes and hollow structural sections is the nominal published mass. The mass per metre of length for bars is the published mass, or if no mass is published, the mass computed from the specified cross-sectional area.

c) *Plates and Slabs.* The mass/area of plates and slabs is computed using the rectangular dimensions of plates or slabs from which the finished plate or slab pieces shown on the shop details can be cut. No burning, cutting, trimming or planning allowance shall be added.

   Only when it is practical and economical to do so, and the nesting configuration is agreed to between the Fabricator and/or Erector and the Client in advance of fabrication (or defined clearly in the Tender Documents), several irregularly-shaped pieces may be cut from the same plate or slab. In this case, the mass shall be computed using the rectangular dimensions of the plate or slab from which the pieces can be cut. No cutting or trimming allowance shall be added. In all cases, the specified plate or slab thickness is to be used to compute the mass. The mass of raised-pattern rolled plate is that published by the manufacturer.

d) *Bolts.* The mass of shop and field bolts, nuts and washers is computed on the basis of the Shop Details and/or Erection Documents and the nominal published mass of the applicable types and sizes of fastener.

e) *Studs.* Unless included in the contract on a "price-per-unit basis", the mass of studs is computed on the basis of the Shop Details and/or Erection Diagrams and the published mass of the studs.

f) *Grating.* The mass/area of grating is computed on the basis of the Shop Details and/or Erection Documents, and the published mass of the grating. The area to be used is the minimum rectangular area from which the piece of grating can be cut.

g) Where supplied, such items as shims, levelling plates, temporary connection material, back-up bars and certain field "consumables" shall be considered as part of the Structural Steel whether or not indicated specifically in the Contract Documents. Such items then will be added to, and become a part of, computed mass of steel for the structure.

3.6 Contract Price Adjustments by Unit Price

3.6.1 Lump Sum Price Contracts

When the responsibility/scope of the Fabricator and/or Erector is changed from that which was previously established by the Contract Documents, an appropriate modification of the contract

price shall be made and specified in a Lump Sum Contract; prices for additions or deletions of materials to the Work may be made on a unit-price basis. In computing the Contract price adjustment, the Fabricator and/or Erector shall consider the quantity of Work added or deleted, modifications in the character of the Work, the timeliness of the change with respect to the status of material ordering, the detailing, fabrication and erection operations, and related impact costs. A suggested format for application of Unit Rates for changes to Work is provided in Appendix B.

3.6.2 Requests for contract price adjustments shall be presented by the Fabricator and/or Erector and shall be accompanied by a description of the change in sufficient detail to permit evaluation and prompt approval by the Client.

3.6.3 Unit-Price Contracts

Generally they provide for minor revisions to the quantity of Work prior to the time Work is approved for construction. Minor revisions to the quantity of Work should be limited to an increase or decrease in the quantity of any category not exceeding ten percent. For Unit-Price Contracts, should the quantity of steel of any category vary by more than twenty percent, then the contract unit price of that category may require adjustment. Changes to the character of the Work or the mix of the Work, at any time, or changes to the quantity of the Work after the Work is approved for construction, may require a contract price adjustment. The unit-price cost of an item subject to changes made after the date of approved Issued–for-Construction Documents shall be evaluated based on the Fabricator's Work in progress at the time of the change, as described in Appendix B.

3.6.4 A suggested format for accommodating contract price adjustments is contained in Appendix B.

3.7 Scheduling

3.7.1 The Contract Documents should specify the schedule for the performance of the Work. This schedule should state when the approved Issued-for-Construction Documents will be issued, and when Shop Details will be submitted and returned from Client review, when the job site, foundations, cores, walls, piers and abutments will be ready, free from obstructions and accessible to the Erector, so that erection can start at the designated time and continue without interference or delay caused by the Client or other trades.

3.7.2 The Fabricator and/or Erector has the responsibility to advise the Client of the effect any revision may have on the Contract schedule.

3.7.3 If the fabrication and erection schedule is significantly delayed due to revisions, or for other reasons which are the Client's responsibility, the Fabricator and/or Erector shall advise the Client in accordance with the requirements of the Contract and the Contract schedule, and the price shall be adjusted as applicable.

4. Contract Documents

4.1 Tender Documents – Tender Drawings and Tender Specifications

4.1.1 At the time tenders are called, the steel Fabricator shall receive a complete set of Tender Documents. In order to ensure adequate and complete tenders for Lump Sum Price Contracts[1], these documents shall include, at minimum, complete Structural Design Documents

[1] *For other types of contracts, it is desirable for the contract documents to be as complete as possible.*

conforming to the requirements for design drawings established in CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code*, as applicable. Structural Steel Construction Specifications should include any special requirements controlling the fabrication and erection of the Structural Steel, surface preparation and coating, and should indicate the extent of non-destructive examination, if any, to be carried out.

4.1.2 Design drawings shall be drawn to a scale adequate to convey the required information. The drawings shall show a complete design of the structure with members suitably designated and located, including such dimensions and detailed description as necessary to permit the preparation of Fabrication and Erection Documents. Floor levels, column centres, and offsets shall be dimensioned. The term "drawings" may include computer output and other data. Stiffeners and doubler plates required to maintain stability and which are an integral part of the main member shall be shown and dimensioned.

4.1.3 Structural Design Documents shall designate the design standards used, shall show clearly the type or types of construction to be employed, shall show the category of the structural system used for seismic design, and shall designate the material or product standards applicable to the members and details depicted. Drawings shall give the governing combinations of shears, moments, pass-through forces, and axial forces to be resisted by the connections. Refer to CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code* for mandated requirements.

4.1.4 Where connections are not shown, the connections shall be assumed to be in accordance with the requirements of the governing technical standard/code (see Clause 1.3). The Tender Documents shall clearly define the scope of Work with respect to the responsibility to design Structural Steel connections. If the Work includes design of Structural Steel connections, the Tender Documents must include all connections forces as required by CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code.* Refer to the applicable standard for mandated requirements.

4.2 Architectural, Electrical and Mechanical Drawings

Architectural, electrical, additional specialty consultant, and mechanical drawings may be used as a supplement to the Structural Design Documents to define detail configurations and construction information, provided all requirements for the Structural Steel are noted on the Structural Documents. Refer to the applicable standard for mandated requirements.

4.3 IFC Construction Documents

4.3.1 At the time specified in the Tender Documents or pre-award negotiations (if different), the Client shall furnish the Fabricator and/or Erector with a plot plan of the construction site, and a set of complete Issued-for-Construction Documents approved for construction consistent with the Tender Documents and any addenda or revisions thereto. These Issued-for-Construction Documents are required by the Fabricator and/or Erector for ordering the material and for the preparation and completion of fabrication and erection documents. The Issued-for-Construction Documents shall conform to the requirements of CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code* and shall show the following:

a) The complete design of the structure with members suitably designated and located, including such dimensions and detailed description as necessary to permit preparation of the Fabrication and Erection Documents. Floor levels, column centres, and offsets shall be dimensioned;

b) All Revisions from the Tender Documents clearly indicated on the IFC Construction Documents

c) All materials to be furnished by the Fabricator, together with sufficient information to prepare Fabrication and Erection Documents, including the design standards used, the type or types of construction to be employed, the category of the system used for seismic design, the applicable material or product standards, and the governing combinations of shears, moments and axial forces to be resisted by connections. Refer to the applicable standard for mandated requirements.

4.4 Architecturally Exposed Structural Steel

In addition to the preceding requirements, all structural elements, or parts thereof, to be treated as Architecturally Exposed Structural Steel must be in accordance with the requirements of Appendix I and clearly indicated on the Structural Design Documents.

4.5 Building Information Digital Modelling

4.5.1 When a project utilizes BIM as part of the Structural Design Documents, Appendix J shall be used as a guide to define the wording, extents and deliverables of BIM in Contract Documents.

4.5.2 The designated Owner of each digital model shall be responsible for the accuracy and maintenance of the model, unless otherwise stated in the Contract Documents.

4.5.3 The Contract shall clearly stipulate the party designated as the Owner of each Building Information Model to be used as part of the Contract Documents.

5. Fabrication and Erection Documents

Note: The term "shop drawings", frequently used in the construction industry, is replaced in this Code of Standard Practice by the terms "Fabrication and Erection Documents". These terms more correctly describe the following five separate and distinct documents that may be prepared by a Fabricator/Erector. See also Clause 1.2 for definitions. Not all of these documents will be required for every project.

5.1 Erection Diagrams

Unless provided by the Client, the Fabricator will prepare Erection Diagrams from the approved Issued-for-Construction Documents. In this regard, the Fabricator may request reproducible copies of the Structural Design Documents which may be altered for use as Erection Diagrams. When using reproducible copies of the Structural Design Documents, the Engineer of Record's name and seal shall be removed. Erection Diagrams shall be submitted to the Designer for review and approval. Erection Diagrams are general arrangement drawings showing the principal dimensions of the structure, piece marks, sizes of the members, size (diameter) and type of bolts, bolt installation requirements, elevations of column bases, all necessary dimensions and details for setting anchor rods, and all other information necessary for the assembly of the structure. Only one reproducible copy, or electronic file, of each diagram will be submitted for review and approval, unless a BIM or a larger number of copies is required by the Client as specified in the Tender Documents.

5.2 Connection Design Details

5.2.1 When so specified in the Contract Documents, Connection Design Details shall be prepared in advance of Shop Details and submitted to the Engineer of Record for confirmation that the intent of the design is met. Connection Design Details shall provide details of standard and non-standard connections, and other data necessary for the preparation of Shop Details. Connection Design Details shall be referenced to the Design Drawings and/or Erection Diagrams. In the event that the design of connections for Structural Steel is the responsibility of the Fabricator, and the Fabricator's Connection Design Details meet the requirements of the Contract and the governing technical standard, any change to the Fabricator's Connection Design Details required by the Engineer of Record shall be considered as a Revision to the scope of Work.

5.2.2 Clipped Double Connections

Where two beams or girders, framing at right angles from opposite sides of a supporting member, share the same bolts, a clipped double connection shall be used unless a seated connection or other detail is used to facilitate safe erection of the beams or girders. A clipped double connection is not applicable to a two-bolt connection or when the beams are equal to or deeper than half the depth of the girder. For a description of a clipped double connection, see Appendix A.

5.3 Shop Details

Unless provided by the Client, Shop Details shall be prepared in advance of fabrication from the information on the approved Issued-for-Construction Drawings, the Connection Design Details, and the Erection Diagrams. Shop Details shall provide complete information required by the Fabricator to complete the fabrication of various members and components of the structure, including the required material and product standards; the location, type, and size of all attachments, mechanical fasteners, and welds. When Shop Details are required to be submitted for review and approval, only one reproducible copy of each Shop Detail will be submitted, unless a digital file or a larger number of copies is required by the Client as part of the Tender Documents. If mentioned in Contract Documents, shop drawing approval can be done using an appropriate BIM approval tool.

5.3.1 Shop Details Furnished by the Client

When the Shop Details are furnished by the Client, he shall deliver them in time to permit fabrication to proceed in an orderly manner according to the time schedule agreed upon. The Client shall prepare these Shop Details, insofar as practicable, in accordance with the detailing standards of the Fabricator. The Client shall indicate, in the Tender Documents, if the BIM and digital manufacturing data will be made available to the Fabricator, and if so, the digital file format that will be provided. The Client shall be responsible for the completeness and accuracy of Shop Details so prepared, and accuracy of the BIM model and digital manufacturing data.

5.4 Erection Procedures

Erection Procedures shall outline the construction methods, erection sequence, Erection Bracing, Temporary Bracing if required, and other engineering details necessary for shipping, erecting, and maintaining the stability of the steel frame; they shall be prepared in accordance with CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code*. Erection Procedures shall be supplemented by drawings and sketches to identify the location of stabilizing elements. Erection Procedures shall be submitted for review when so specified.

5.5 Field Work Details

Field Work Details shall be prepared in accordance with CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code* and submitted to the designer for review and approval. Field Work Details shall provide complete information for modifying fabricated members on the job site. All operations required to modify the member shall be shown on the Field Work Details. If extra materials are necessary to make modifications, Shop Details shall be required.

5.6 Fabrication and Erection Document Review

Erection Diagrams, non-standard Connection Design Details, Shop Details, and Field Work Details are normally submitted for review by the Engineer of Record. The duration required for such review shall be stated in the Tender Documents so that the Fabricator can prepare his schedule accordingly. Review of submitted documents by the Engineer of Record indicates that the Fabricator has interpreted correctly the design and Construction requirements. Connection Design Details and Shop Details are reviewed by the Engineer of Record for structural adequacy and to ensure conformance with the loads, forces and special instructions contained in the Structural Design Documents. Review by the Engineer of Record of Shop Details submitted by the Fabricator does not relieve the Fabricator of the responsibility for accuracy of the detail dimensions on Shop Details, nor of the general fit-up of parts to be assembled.

5.7 Additions, Deletions or Changes

Additions, deletions or changes, when approved, will be considered as Contract revisions and constitute the Client's authorization to release the additions, deletions or revisions for construction. See also Clauses 3.3 and 3.6.

5.8 Fabricator Models

When a Fabricator uses self-prepared three-dimensional software (BIM) specifically for his Work, the Fabricator owns the model and data.

6. Material, Fabrication, Inspection, Painting and Delivery

6.1 Quality Certification

For projects requiring a demonstrated level of quality control, CISC Certification of Steel Structures or CISC Certification of Steel Bridges may be specified.

CISC Certification is a third-party audited quality certification program specific to the fabrication of steel structures or steel bridges.

6.2 Materials

Materials used by the Fabricator for structural use shall conform to those listed in CSA S16, *Design of steel structures* or *S6 Canadian highway bridge design code*, or to other published material specifications, in accordance with the requirements of the Construction Documents.

6.3 Identification

The method of identification stipulated in CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code* shall form the basis for a Fabricator's identification of material. Control and identification procedures may differ to some extent from Fabricator to Fabricator.

6.4 Preparation of Material

Preparation of Material shall conform to the requirements of CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code.* Flame or plasma cutting of Structural Steel may be done by hand, by mechanically guided means, or automatically as permitted by the applicable governing Code.

6.5 Fitting and Fastening

6.5.1 Projecting elements of connection attachments need not be straightened in the connecting plane if it can be demonstrated that installation of the connectors or fitting aids will provide adequate contact between faying surfaces.

6.5.2 When runoff tabs are used, the Fabricator and/or Erector need not remove them unless specified in the Structural Design Documents, required by the governing technical Code or the steel is exposed to view. When their removal is required, they may be hand flame-cut close to the edge of the finished member with no more finishing required, unless other finishing is specifically called for in the Structural Design Documents or the governing technical Code.

6.6 Dimensional Tolerances

Tolerances on fabricated members shall be those prescribed in CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code*, as applicable. Tolerances on steel material supplied by the Fabricator shall meet those prescribed in CSA Standard G40.20 or the applicable ASTM Standard.

6.7 Inspection of Steelwork

Should the Client wish to have an independent inspection and/or non-destructive examination of the steelwork, he shall reserve the right to do so in the Tender Documents. Inspections shall be coordinated between the Fabricator and/or Erector and the Client's inspector. Inspectors are to be appointed prior to the start of fabrication, and the Client is to advise the Fabricator of the arrangement made. The cost of this inspection and testing is the responsibility of the Client. Deficiencies in the Work of the Fabricator and/or Erector requiring re-inspection or re-testing shall have costs borne by the Fabricator and/or Erector. Third-party inspectors shall be duly certified and have sufficient experience for the type of inspection performed.

The Fabricator and/or Erector is responsible for providing a conforming product through internal inspection, quality control, quality assurance and any other means necessary. The Fabricator and/or Erector's personnel used for internal visual inspection, QC or QA shall not be required to hold a visual certification to a National Standard, provided the company has assessed their competency for the Work performed.

The Canadian Welding Bureau Letter of Validation is proof that the Fabricator and/or Erector is certified for welding to CSA Standard W47.1. The applicable welding procedure standards, welding procedure data sheets, and personnel qualifications shall be available for review and verification by the Client or his representative at the place of Work, and are not intended for submission to the Client.

6.8 Surface Preparation

Unless required for a specified coating system, fabricated steelwork will not be cleaned. Surface preparation for a specified coating system shall be described in the Structural Design Documents.

If paint is specified, the Fabricator shall clean all steel surfaces to be painted of loose rust, loose mill scale, prominent spatter, slag or flux deposit, oil, dirt and other foreign matter by wire brushing or other suitable means. Unless specified in the Construction Documents, the Fabricator shall not be obliged to blast-clean, pickle or perform any specific surface preparation operation aimed at total or near-total removal of tight mill scale, rust or non-deleterious matter.

6.9 Paint Coatings

When Structural Steel is specified to receive a shop coating, the coating requirements specified in the Tender Documents shall include the identification of the members to be painted, surface preparation, application specification, the manufacturer's product identification, and the required minimum (and maximum) dry film thickness, if required. The Fabricator shall be responsible only to the extent of performing the surface preparation and painting in the specified manner. To the extent that the Fabricator has met these requirements, the Fabricator is not responsible for the performance of the specified coating system in the service conditions and duration to which the steelwork is exposed.

The expected performance of steel with a shop coat of primer depends on the environment. The primer will provide temporary limited corrosion protection to the steel in an essentially non-corrosive atmosphere for durations not exceeding 6 or 12 months for a CISC/CPMA 1-73a or CISC/CPMA 2-75 primer respectively, or according to the manufacturer's specifications and limitations. These durations apply to installed steel or steel that is not subjected to a corrosive environment in its erected state. Uninstalled steel stored flat with the potential for water accumulation on horizontal surfaces may, in some situations, be considered a corrosive environment. The presence of minor rust bleed-through, especially between unpainted faying surfaces, is not to be considered as a failure of the paint system and is not a cause for rejection or corrective action by the Fabricator.

Unless otherwise specified, coating systems applied by steel Fabricators are for temporary corrosion protection and are not intended for esthetic or final architectural purposes. For complex anti-corrosive multi-coat industrial coating systems or architecturally exposed Structural Steel paint systems, the Fabricator's inspection and test plan for coating applications shall be approved by the Client prior to commencement of the Work. The use of samples may be agreed upon as acceptance criteria. The Client is required to approve the coating application process on an ongoing basis throughout the execution of the project.

6.10 Marking and Shipping

6.10.1 Except for weathering steel surfaces exposed to view and for architecturally exposed Structural Steel (AESS) (see also Appendix I), erection marks shall be painted or otherwise legibly marked on the members. Preferably, members which are heavy enough to require special erection equipment shall be marked to indicate the computed or scale mass, and the centre of gravity for lifting.

6.10.2 Bolts of the same length and diameter, and loose nuts and washers of each size shall be packaged separately. Pins, bolts, nuts, washers, and other small parts shall be shipped in boxes, crates, kegs or barrels, none of which are to exceed 135 kg gross mass. A list and description of material contained therein shall be marked plainly on the outside of each container.

6.10.3 When requested by the Erector, long girders shall be loaded and marked so that they will arrive at the job site in position for handling without turning. Instructions for such delivery shall be given to the carrying agency when required.

6.10.4 For each shipment, the Fabricator shall furnish a shipping bill listing the items in the shipment. Such bill shall show the erection mark, the approximate length, the description (whether beam, column, angle, etc.) of each item. Such bill shall be signed by the receiver and returned to the Fabricator within 48 hours of receipt of the shipment with a note regarding shortages or damages, if any, and the bill shall act as a receipt for the shipment. When the shipments are made by truck transport, the bills should accompany the shipment. When shipments are made by rail or water, the bills shall be sent to the receiver to arrive on or before receipt of the shipment.

6.10.5 Unless otherwise specified at time of tender, steel during shipment will not be covered by tarpaulins or otherwise protected. When such protection is specified, the shipper is to notify the carrier of the protection requirements.

6.11 Delivery of Materials

6.11.1 Fabricated Structural Steel shall be delivered in a sequence which will permit the most efficient and economical performance of shop fabrication and erection. If the Client contracts separately for delivery supply and erection, he must coordinate planning between the Fabricator, Erector and General Contractor as applicable.

6.11.2 Anchor rods, washers and other anchorages, grillages, or materials to be built into masonry or concrete should be shipped so that they will be on hand when needed. The Client must give the Fabricator sufficient notice to permit fabrication and shipping of materials before they are needed.

6.11.3 The size and mass of Structural Steel assemblies may be limited by the shop capabilities, the permissible mass and clearance dimensions of available transportation or government regulations, and the job site conditions. The Fabricator determines the number of field splices consistent with economy. The Engineer of Record shall review and accept splice locations prior to implementation.

6.11.4 On supply-only Contracts, the unloading of steel is the responsibility of Others. Unless stated otherwise, the unloading of steel is part of the steel erection.

7. Erection

7.1 Method of Erection

Unless otherwise specified or agreed upon, erection shall proceed according to the most efficient and economical method available to the Erector on the basis of continuous operation consistent with the Construction Documents.

7.2 Erection Stability

7.2.1 Design

7.2.1.1 The Engineer of Record shall identify the following in the Tender Documents:

a) The lateral-load-resisting system and connecting diaphragm elements that provide for lateral strength and stability in the completed structure.

b) Any special erection conditions or other considerations that are required by the design concept, such as the use of shores, jacks, or loads that must be adjusted as erection progresses to set or maintain camber, position within specified tolerances, or pre-stress.

7.2.1.2 The General Contractor shall indicate to the Fabricator and/or Erector the general construction execution plan, including the installation schedule for non-structural steel elements of the lateral-load-resisting system and connecting diaphragm elements. The General Contractor shall indicate requirements for Temporary Bracing to accommodate this plan.

7.2.1.3 Based upon the information provided in Sections 7.2.1 and 7.2.2, the Fabricator and/or Erector shall determine, furnish, and install all Erection Bracing required for the erection operation. This Temporary Bracing shall be sufficient to secure the skeletal Structural Steel framing or any portion thereof against loads that are likely to be encountered during erection, including those due to wind and those that result from erection operations.

7.2.1.4 The Fabricator and/or Erector need not consider loads during erection that result from the performance of Work by, or the acts of Others, except as specifically identified by the Engineer of Record and/or the General Contractor, nor those that are unpredictable, such as loads due to hurricane, tornado, earthquake, explosion, or collision.

7.2.1.5 Temporary Bracing that is required during or after the erection of the Structural Steel Frame, including steel deck, for the support of loads caused by non-Structural Steel elements, including cladding, interior partitions, and other such elements that will induce or transmit loads to the Structural Steel frame during or after erection, shall be the responsibility of the Engineer of Record or General Contractor, as applicable.

7.2.1.6 The Structural Steel Fabricator and/or Erector shall engage the steel deck contractor to provide a bundle layout (including locations and weights) for the landing of deck bundles based on the Structural Steel erection plan.

7.2.2 Steel Erection Execution

7.2.2.1 The Steel Erection Execution Plan provides for a sequentially erected structure. The full stability of the structure is not achieved until all of the lateral support systems are in place. Proceeding with subsequent non-structural construction prior to completion shall be at the instruction and sole risk of the General Contractor, who shall make the Erector aware of the special provisions in place to accommodate any collateral building loads.

7.2.2.2 The instruction/request to proceed with the Structural Steel erection and steel deck installation will be given by the General Contractor following agreement between all parties that the following events have taken place.

a) The Erection Diagrams and steel deck drawings have been reviewed by the Engineer of Record.

b) The Steel Erection Execution Plan has been reviewed by the General Contractor and approved in principle for compliance with his construction execution plan.

At this time, a formal review shall be completed by all parties, and Work may proceed.

7.2.2.3 During the construction period, any other trade contractor placing a load on a steel framing member shall ensure that the load is distributed so as not to exceed the carrying capacity of the subject steel framing member.

7.2.2.4 Prior to placement of steel deck bundles, communication between the General Contractor, the steel deck installer, and the structural Fabricator and/or Erector has taken place to ensure that all requirements of the Steel Erection Execution Plan have been met and it is

agreed that the structure (full or partial) is ready to accept the construction loads of the steel deck.

7.2.2.5 Once the deck installation and required inspections have been completed, and deficiencies addressed, responsibility for structural stability is assumed by the General Contractor.

7.2.2.6 The erection execution plan may be modified, and costs accommodated, to suit specific project requirements, pre- or post-bid, providing the Owner's designated representative for construction has clearly stated these requirements, and they may be accomplished in a safe manner.

Temporary Bracing of the steel frame shall only be removed on instruction from the Engineer of Record.

7.3 Erection Safety

Erection shall be done in a safe manner and in accordance with applicable provincial legislation.

7.4 Site Conditions

The Client shall provide and maintain adequate, all-weather access roads cleared of snow and ice and other material that impedes entry into and through the site for the safe delivery of derricks, cranes, other necessary equipment, and the material to be erected. The Client shall provide for the Erector a firm, properly graded, drained, convenient and adequate space and laydown area for steel of sufficient load-carrying capacity at the site for the operation of erection equipment, and shall remove at the Client's cost all overhead obstructions such as power lines, telephone lines, etc., in order to provide a safe and adequate working area for erection of the steelwork. The Erector shall provide and install the safety protection required for his own operations or for his Work forces to meet the safety requirements of applicable Acts or Codes. The General Contractor shall install protective covers on all protruding rebar, machinery, anchor rods, etc., which are a hazard to workers and shall be installed by other trades prior to commencement of steel erection. Any protection for pedestrians, property, other trades, etc., not essential to the steel erection activity is the responsibility of the Client. When the structure does not occupy the full available site, the Client shall provide adequate storage space to enable the Fabricator and Erector to operate at maximum practicable speed and efficiency. Cleaning of steelwork required because of site conditions, mud, site worker traffic, etc., shall not be to the Fabricator's and/or Erector's account.

7.5 Foundations

Neither the Fabricator nor the Erector shall be responsible for the accurate location, strength and suitability of foundations.

7.6 Bearing Surfaces

Levelling plates shall be set by other trades true, level and to the correct elevation.

7.7 Building Lines and Bench Marks

The Erector shall be provided with a plot plan accurately locating building lines and bench marks at the site of the structure. A survey bench mark establishing elevation and horizontal coordinates shall be provided by the Client at the site.

7.8 Installation of Anchor Rods and Embedded Items

7.8.1 Anchor rods and foundation rods shall be set by others in accordance with the Construction Documents. They must not vary from the dimensions shown on the Construction Documents by more than the following (see also Appendix D):

a) 3 mm centre-to-centre of any two rods within an anchor rod group, where an anchor rod group is defined as the set of anchor rods which receives a single fabricated steel shipping piece; 6 mm centre-to-centre of adjacent anchor rod groups;

b) Maximum accumulation of 6 mm per 30 000 mm along the established column line of multiple anchor rod groups, but not to exceed a total of 25 mm. The established column line is the actual field line most representative of the centres of the as-built anchor rod groups along a line of columns;

c) 6 mm from the centre of any anchor rod group to the established column line through that group. Shims: the finished tops of all footings shall be at the specified level which will not exceed the maximum specified grouting allowance to predetermine the amount of shimming that will be required.

The tolerances of paragraphs (a), (b), and (c) also apply to offset dimensions, shown on the Construction Documents, measured parallel and perpendicular to the nearest established column line for individual columns shown on the drawings to be offset from established column lines.

7.8.2 Unless shown otherwise, anchor rods shall be set perpendicular to the theoretical bearing surface, threads shall be protected, free of concrete, and nuts should run freely on the threads. Shear pockets shall be cleaned of debris, formwork, ice and snow by the Client prior to steel erection.

7.8.3 Other embedded items or connection materials between the Structural Steel and the Work of Others shall be located and set by Others in accordance with approved Construction Documents. Accuracy of these items must satisfy the erection tolerance requirements of Clause 7.12.

7.8.4 All Work performed by Others shall be completed so as not to delay or interfere with the erection of the Structural Steel.

7.9 Bearing Devices

The Client shall set to lines and grades all levelling plates and loose bearing plates. The Fabricator and/or Erector shall provide the wedges, shims or levelling screws that are required, and shall scribe clearly the bearing devices with working lines to facilitate proper alignment. Promptly after the setting of any bearing devices, the Client shall check lines and grades, and grout as required. The final location and proper grouting of bearing devices are the responsibility of the Client.

When steel columns, girders or beams which will be supported on concrete or masonry have base plates or bearing plates fabricated as an integral part of the member, the bearing area of the support shall be suitably prepared by Others so as to be at exact grade and level to receive the steelwork.

7.10 Site Errors or Discrepancies – Examination by Erector

The Erector shall report to the Client any errors or discrepancies in the Work of Others, as discovered, that may affect erection of Structural Steel before or during erection. The accurate

placement and integrity of all anchor rods/embedment etc., remain the responsibility of the Client.

7.11 Adjustable Shelf Angles and Sash Angles

The Erector shall position at time of erection all adjustable shelf angles and sash angles attached to the steel frame true and level, within the tolerances permitted by the governing technical standard. Any subsequent adjustment that may be necessary to accommodate the Work of Others shall be performed by other trades.

7.12 Tolerances

Unless otherwise specified, tolerances on erected Structural Steel shall be those prescribed in CSA S16, *Design of steel structures* or S6 *Canadian highway bridge design code* as applicable.

7.13 Checking Erected Steelwork

Prior to the placement or applying of any other material of any other trades, the Client shall:

- Confirm with the Erector that the structure is complete and conforming to the Construction Documents, and
- Confirm that any third-party inspection and testing and necessary corrective action have been completed, and
- Ensure that the Erector is given timely notice of acceptance by the Client or a listing of specific items to be corrected in order to obtain acceptance, and
- Ensure such notice is rendered immediately upon completion of any part of the Work and prior to the start of Work by other trades that may be supported, attached or applied to the structural steelwork.

Should such notice not be received within 14 days, or the Client commences use, occupancy, or improvement to the steelwork, then the Work is taken to have been accepted.

The Erector is not responsible for determining or effecting the stability of the structure due to temporary loads resulting from construction activities of Others.

7.14 Removal of Bracing

7.14.1 Removal of Erection Bracing

Guys, braces and falsework or cribbing supplied by the Erector shall remain the property of the Erector. The Erector shall remove them when the steel structure is otherwise adequately braced, unless other arrangements are made. Guys and braces temporarily left in place under such other arrangements shall be removed by Others, provided prior permission by the Erector for their removal has been given and they are returned to the Erector in good condition. See Clause 7.14.2.

7.14.2 Removal of Temporary Bracing

Temporary Bracing required by the structural designer shall only be removed on instruction from the Engineer of Record.

7.15 Correction of Errors When Material Is Not Erected by the Fabricator

Correction of minor misfits and a moderate amount of cutting, welding, and reaming for the project as a whole shall be considered a part of the erection, in the same manner as if the Fabricator were erecting the Work. Any major rework required due to incorrect shop Work shall be immediately reported to the Fabricator before rework commences. The Fabricator shall then either correct the error, resupply the item within a reasonable time period, or approve the method of correction including applicable costs, whichever is the most economical. The definitions of major and minor rework should be agreed to prior to the commencement of the project.

7.16 Field Assembly

Unless otherwise specified, the Fabricator shall provide for suitable field connections that will, in his opinion, afford the greatest overall economy.

7.17 Accommodation of Other Trades

Neither the Fabricator nor the Erector shall cut, drill or otherwise alter the Work of Others or his own Work to accommodate other trades, unless such Work is clearly defined in the Structural Steel and Tender Documents, and detailed information is provided before the Erection Documents are approved. Any subsequent cutting, drilling or other alteration of the Structural Steel performed by the Fabricator or the Erector for the accommodation of other trades shall be specifically agreed upon and authorized by the Client before such Work is commenced.

7.18 Temporary Floors and Access Stairs

Unless otherwise required by law or in the Tender Documents, all temporary access stairs shall be provided by Others, except for the floor upon which erecting equipment is located. On this floor, the Erector shall provide such temporary flooring as he requires, moving his planking, etc., as the Work progresses.

7.19 Touch-Up of Shop Paint Coatings

Touch-up may also be required for unfinished field bolts or at masked connection areas. It is normal to expect that painted or coated Structural Steel surfaces will be subject to damage due to handling from loading, off- loading and installation, and due to abrasions during shipment. Unless so specified, the Fabricator and/or Erector will not perform any field coating touch-ups, spot-paint field fasteners and field welds, nor touch-up abrasions to the shop paint.

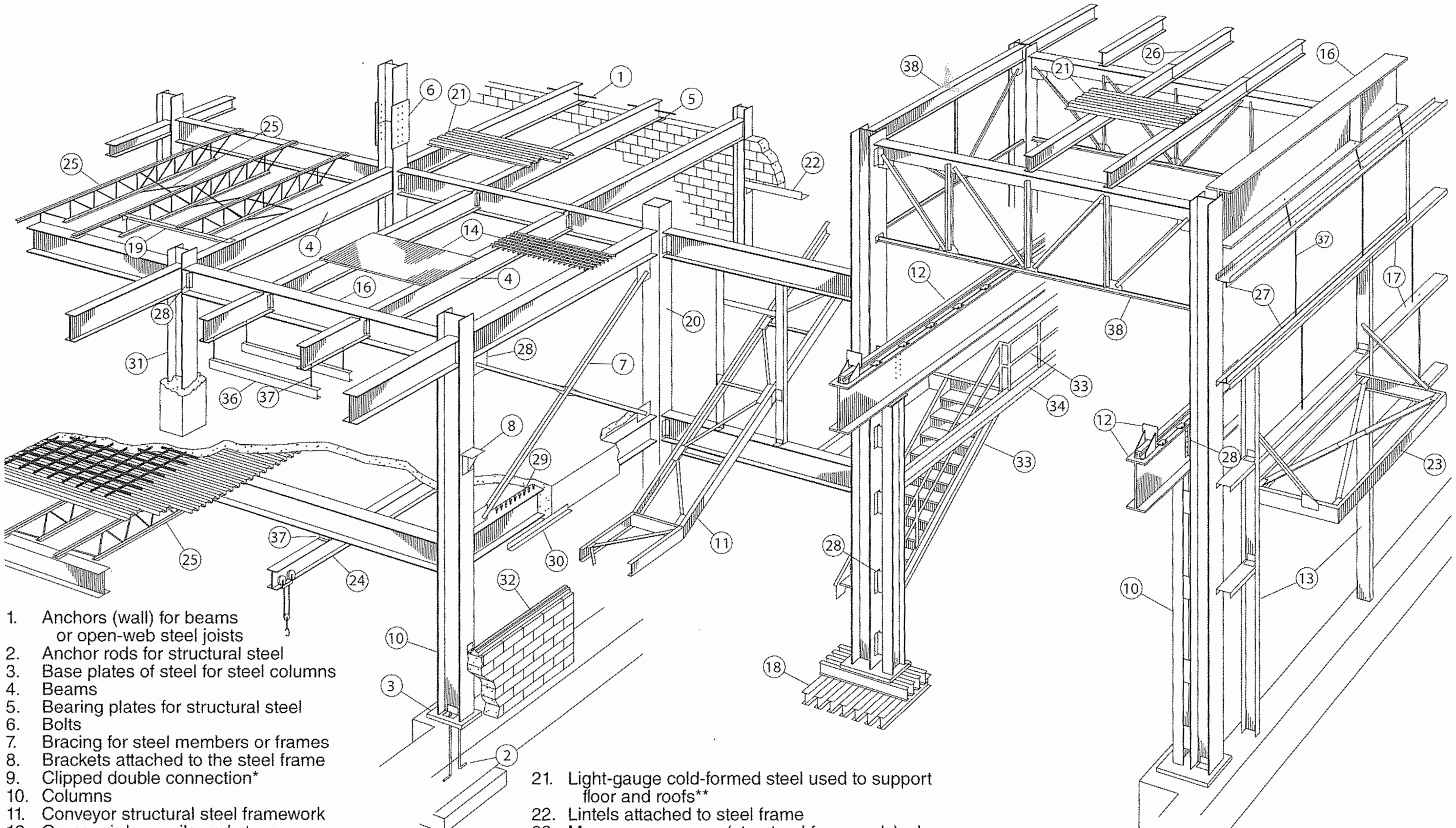
7.20 Final Painting

Unless so specified, the Fabricator and/or Erector will not be responsible for cleaning the steel after erection in preparation for field painting, nor for any general field painting that may be required.

7.21 Final Cleanup

Except as provided in Clause 7.14, upon completion of erection and before final acceptance, the Erector shall remove all falsework, rubbish and temporary building furnished by him.

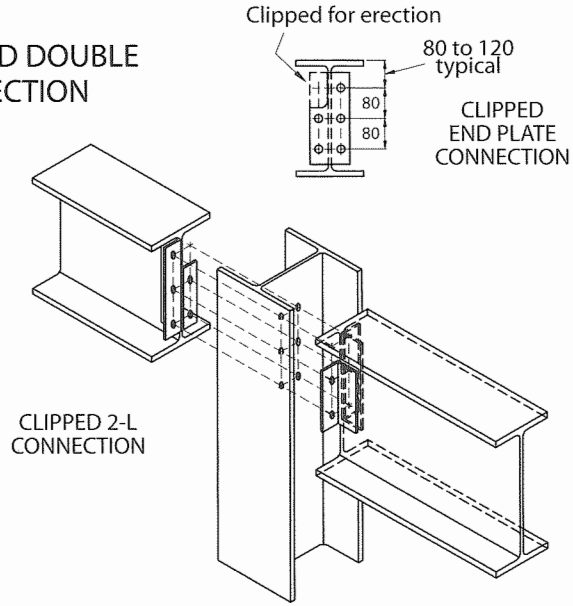
APPENDIX A – Structural Steel in Buildings

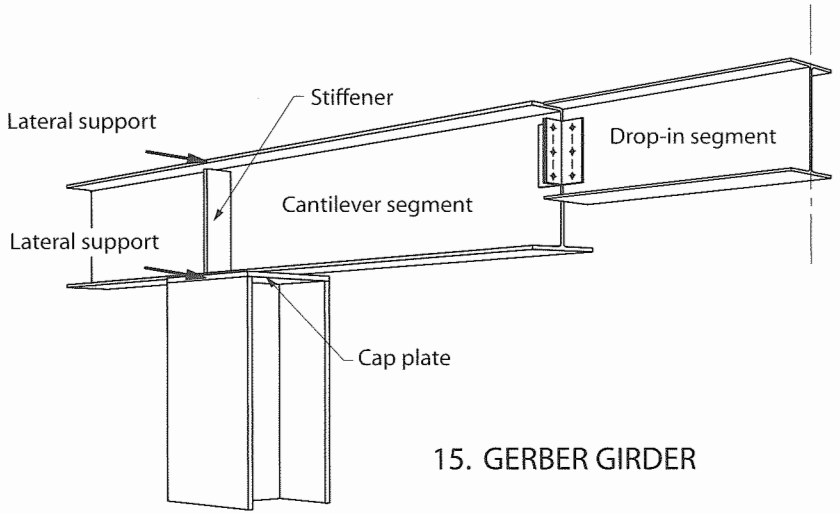


1. Anchors (wall) for beams or open-web steel joists
2. Anchor rods for structural steel
3. Base plates of steel for steel columns
4. Beams
5. Bearing plates for structural steel
6. Bolts
7. Bracing for steel members or frames
8. Brackets attached to the steel frame
9. Clipped double connection*
10. Columns
11. Conveyor structural steel framework
12. Crane, girders, rails and stops
13. Door frames constituting part of and connected to the steel frame
14. Floor and roof plates (raised pattern or plain), grating, connected to steel frame
15. Gerber girder*
16. Girders
17. Girts
18. Grillage beams of steel
19. Headers or trimmers for support of open-web steel joists where such headers or trimmers frame into structural steel members
20. Hollow structural section (HSS) column
21. Light-gauge cold-formed steel used to support floor and roofs**
22. Lintels attached to steel frame
23. Marquee or canopy (structural frame only) when forming an integral part of the steel frame
24. Monorail beams of standard structural shapes, attached to steel frame
25. Open-web steel joists, bridging and accessories when supplied with steel joists
26. Purlins
27. Sash angles connected to the steel frame
28. Separators, angles, tees, clips and other detail fitting essential to the structural steel frame
29. Shear connectors
30. Shelf angles attached to the steel frame
31. Steel cores for composite columns
32. Steel window sills attached to the steel frame
33. Steel stairs and handrails
34. Struts
35. Stub girders*
36. Suspended ceiling supports of structural steel shapes 75 mm or greater in depth
37. Ties, hangers and sag rods forming part of the structural frame
38. Trusses and braced frames

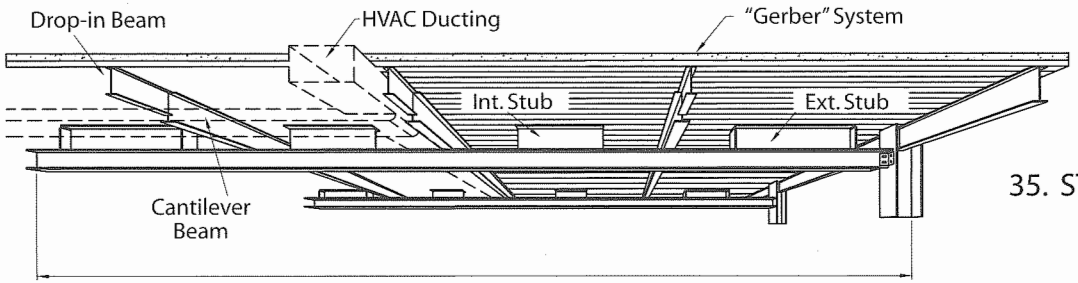
** See separate diagram*   *** Supplied by others*

9. CLIPPED DOUBLE CONNECTION





15. GERBER GIRDER



35. STUB-GIRDER

APPENDIX B

Guideline for Unit Price Application for Changes

B1. Unit rates for Changes shall apply on their own, only up until commencement of material order or shop detail drawings, whichever is the earlier.

B2. It is accepted that Unit Rates for additions will be higher than for rates for deletions. Unit Rates for both additions and deletions should be requested in the Tender Documents if Unit Prices are to be used for the project.

B3. The following amounts, additional to the unit rate, shall be charged on additions at the various stages of the contract.

a) If the addition affects drawings (e.g. of support members) already in progress or complete, then the changes to such drawings or re-detailing shall be charged extra at an agreed hourly rate.

b) If the addition requires additional Work to material manufacture or erection (e.g. supporting members) in progress or complete, then such additional Work shall be charged extra at an agreed hourly rate.

c) "Detail" or "Connection" materials added to existing or supporting members, whether due to an additional member or not, shall be charged on a cost-plus basis.

d) If the timing of the addition causes the added material to be shipped as a part load, then transportation shall be charged extra at cost plus an agreed percentage markup.

B4. The following amounts, additional to the unit rate, shall be charged for deletions at the various stages of the contract.

a) If the deleted material has been ordered or delivered and cannot be used elsewhere, then a restocking charge shall be levied.

b) If the deleted member has been detailed or drawings are in progress, then the cost of such drawings shall be charged extra at an agreed hourly rate.

c) If the deletion affects drawings already completed or in progress, then the changes to such drawings or the re-detailing shall be charged extra at an agreed hourly rate.

d) If the deleted member has been manufactured or erected, or manufacture or erection is in progress, then the cost of such manufacture or erection shall be charged extra at an agreed hourly rate or lump sum cost.

e) If the deletion affects members already manufactured (e.g. supporting members), then the changes to such members shall be charged extra at an agreed hourly rate or lump sum cost.

f) If the deleted member has already been shipped, then no credit shall be given.

B5. All unit rates shall be applied in accordance with the CISC Code of Standard Practice, Clause 3.5.

B6. Hourly Rates for additions are as follows:

a) Engineering Design – $ / labour hour

b) Detailing Labour – $ / labour hour

c) Shop Labour – $ / labour hour

d) Field Labour – $ / labour hour

e) Equipment used for revisions will be charged at negotiated rental rates, according to Canadian Construction Association standard practice.

B7. Revisions involving the use of grades of steel, sources of supply, or types of sections other than specified will be subject to price adjustments.

B8. Mass will be computed in accordance with Clause 3.5 of the CISC Code of Standard Practice for Structural Steel.

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C1

It is common practice in the industry to limit categories for structural steel to light, medium and heavy steel members. These very general categories require the Fabricator to make allowance for the very large degree of complexity that may be encountered in the final project design. This comprehensive category list removes variability of complexity from each category, enabling a more economical price evaluation for each category.

CAT NUM	CLASSIFICATION	PAY UNIT
	Columns and Beams - Rolled Sections	
100	0 to 15 kg/m	tonne
101	16 to 30 kg/m - 0-3 m	tonne
102	16 to 30 kg/m - 3-9 m	tonne
103	16 to 30 kg/m - >9 m	tonne
104	31 to 60 kg/m - 0-3 m	tonne
105	31 to 60 kg/m - 3-9 m	tonne
106	31 to 60 kg/m - >9 m	tonne
107	61 to 90 kg/m - 0-3 m	tonne
108	61 to 90 kg/m - 3-9 m	tonne
109	61 to 90 kg/m - >9 m	tonne
110	91 to 155 kg/m - 0-3 m	tonne
111	91 to 155 kg/m - 3-9 m	tonne
112	91 to 155 kg/m - >9 m	tonne
113	>155 kg/m - 0-3 m	tonne
114	>155 kg/m - 3-9 m	tonne
115	>155 kg/m - >9 m	tonne
	Columns and Beams - HSS/RHS Sections	
116	0 to 30 kg/m - 0-3 m	tonne
117	0 to 30 kg/m - 3-9 m	tonne
118	0 to 30 kg/m - >9 m	tonne
119	31 to 60 kg/m - 0-3 m	tonne
120	31 to 60 kg/m - 3-9 m	tonne
121	31 to 60 kg/m - >9 m	tonne
122	>60 kg/m - 0-3 m	tonne
123	>60 kg/m - 3-9 m	tonne
124	>60 kg/m - >9 m	tonne

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C1 (Cont'd)

	Monorails and Crane Rails	
150	S Shapes - Straight - 0-30 kg/m	tonne
151	S Shapes - Straight - over 30 kg/m	tonne
152	S Shapes - Rolled - 0-30 kg/m	tonne
153	S Shapes - Rolled - over 30 kg/m	tonne
154	30 lb Crane Rail c/w Clips	tonne
155	60 lb Crane Rail c/w Clips	tonne
156	85 lb Crane Rail c/w Clips	tonne
	Bracing	
201	Rld Sec - 0 to 30 kg/m - <3 m	tonne
202	Rld Sec - 0 to 30 kg/m - 3-9 m	tonne
203	Rld Sec - 0 to 30 kg/m - >9 m	tonne
204	Rld Sec - >30 kg/m - <3 m	tonne
205	Rld Sec - >30 kg/m - 3-9 m	tonne
206	Rld Sec - >30 kg/m - >9 m	tonne
210	HSS Sec - 0 to 30 kg/m - <3 m	tonne
211	HSS Sec - 0 to 30 kg/m - 3-9 m	tonne
212	HSS Sec - 0 to 30 kg/m - >9 m	tonne
213	HSS Sec - >30 kg/m - <3 m	tonne
214	HSS Sec - >30 kg/m - 3-9 m	tonne
215	HSS Sec - >30kg/m - >9 m	tonne
220	WT Sec - 0 - 30 kg/m - <3 m	tonne
221	WT Sec - 0 - 30 kg/m - 3-9 m	tonne
222	WT Sec - 0 - 30 kg/m - >9 m	tonne
223	WT Sec - >30 kg/m - <3 m	tonne
224	WT Sec - >30 kg/m - 3-9 m	tonne
225	WT Sec - >30 kg/m - >9 m	tonne
	Built-Up Members	
250	3 Plate Girders <90 kg/m	tonne
251	3 Plate Girders 90-155 kg/m	tonne
252	3 Plate Girders >155 kg/m	tonne
260	Fireproofing Corner Angles	tonne
261	Continuous Support Angles for Deck, etc.	tonne
262	Bent Plates	tonne

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C1 (Cont'd)

	Cold-Formed Channels and Z-Shapes	
301	0 - 5.75 kg/m - 0-3 m	tonne
302	0 - 5.75 kg/m - 3-9 m	tonne
303	0-5.75 kg/m - >9 m	tonne
304	> 5.75 kg/m - 0-3 m	tonne
305	> 5.75 kg/m - 3-9 m	tonne
306	> 5.75 kg/m - >9 m	tonne
320	Sag Rods - specify diameter and finish	tonne
	Connection Materials and Welding	
401	Welded Plates - Gusset Plates, Wrap Plates, Shear Tabs	tonne
402	Welded Plates - Moment Plates	tonne
403	Welded Plates - End Plates, Clip Angles	tonne
404	Welded Plates - Base/Cap Plates	tonne
405	Welded Plates - Stiffeners under W310	tonne
406	Welded Plates - Stiffeners W360 to W460	tonne
407	Welded Plates - Stiffeners W460 to W610	tonne
408	Welded Plates - Web Doubler Plates	tonne
409	Welded Plates - Shop Welded Lifting Lugs	tonne
410	Welded Plates - Bolted Lifting Lugs	tonne
411	Loose Plates - Field-Installed	tonne
412	Prepared Groove Welds	cm^3
413	Seal Welding	cm
414	Welded Shear Studs	ea
	Miscellaneous	
501	Stair Stringers	tonne
502	Shop Assembled Stairs - Stringers and Bolted Treads	tonne
503	Ladders (without safety cage)	tonne
504	Ladder (with safety cage)	tonne
505	Checkerplate: 6 mm thick - specify installation location and method	tonne
506	Checkerplate: 8 mm thick - specify installation location and method	tonne
507	Handrail (straight)	tonne
508	Handrail (sloped)	tonne
509	Handrail (circular)	tonne
510	Safety gates: Premanufactured	Ea
511	Safety gates: Steel Fabricated	Ea

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C1 (Cont'd)

	Grating and Treads	
601	Stair Treads (specify Bearing Bar Size, tread size surface type, finish)	Ea
603	Grating (specify Bearing Bar Size, tread size surface type, finish)	m^2
605	Cold-Formed Walkway Channels	m
606	Cold-Formed Walkway Channel fasteners	Ea
607	Grating - Straight Banding (shop)	m
608	Grating - Circular Banding (shop)	m
609	Grating - Straight Toe Plate (shop)	m
610	Grating - Circular Toe Plate (shop)	m
611	Grating - Grating Clip (specify type)	Ea
612	Grating - Checkerplate Nose to Grating	m
	Welded Frames (2 or more shop-welded framing members)	
701	Members - 0 - 15 kg/m	tonne
702	Members - 16 - 30 kg/m	tonne
703	Members - 31 - 60 kg/m	tonne
704	Members - 61 - 90 kg/m	tonne
705	Members - 90 - 155 kg/m	tonne
	Bolts	
801	A307 16 mm (5/8) dia. (Black) or 10 mm (3/8) dia. (Plated) x length	Ea / tonne
802	A325 Bolt (Black): 20 mm (3/4) dia. x length	Ea / tonne
803	A325 Bolt (Black): 22 mm (7/8) dia. x length	Ea / tonne
804	A325 Bolt (Black): 25 mm (1) dia. x length	Ea / tonne
805	A490 Bolt (Black): 32 mm (1 1/4) dia. x length	Ea / tonne
806	B307 (Button Head): 16 mm (5/8) dia. x length	Ea / tonne
	Hourly Rates for Extra Work	
	Extra Engineering Design	hour
	Extra Drafting Labour	hour
	Extra Shop Labour	hour
	Extra Field Labour	hour
	Extra Administration Labour	hour

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C2

In the event that the comprehensive Category List C1 is deemed too onerous to manage, Category List C2 provides an alternate approach. The categories in this list include a greater variation in complexity but may be deemed easier to manage.

CAT NUM	CLASSIFICATION	PAY UNIT	Comments
	Columns and Beams - Rolled Sections		
100	0 to 15 kg/m	tonne	
101	16 to 30 kg/m	tonne	
104	31 to 60 kg/m	tonne	
107	61 to 90 kg/m	tonne	
110	91 to 155 kg/m	tonne	
113	>155 kg/m	tonne	
	Columns and Beams - HSS/RHS Sections		
116	0 to 30 kg/m	tonne	
119	31 to 60 kg/m	tonne	
122	>60 kg/m	tonne	
	Monorails and Crane Rails		
150	S Shapes - Straight	tonne	
151	S Shapes - Straight	tonne	
152	S Shapes - Rolled	tonne	
153	S Shapes - Rolled	tonne	
154	30 lb Crane Rail c/w Clips	tonne	
155	60 lb Crane Rail c/w Clips	tonne	
156	85 lb Crane Rail c/w Clips	tonne	
	Bracing		
201	Rld Sec - 0 to 30 kg/m	tonne	
204	Rld Sec - >30 kg/m	tonne	
210	HSS Sec - 0 to 30 kg/m	tonne	
213	HSS Sec - >30	tonne	
220	WT Sec - 0 - 30 kg/m	tonne	
223	WT Sec - >30 kg/m	tonne	

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C2 (Cont'd)

	Built-Up Members		
250	3 Plate Girders <90 kg/m	tonne	
251	3 Plate Girders 90-155 kg/m	tonne	
252	3 Plate Girders >155 kg/m	tonne	
260	Fireproofing Corner Angles	tonne	
261	Continuous Support Angles for Deck, etc.	tonne	
262	Bent Plates	tonne	
	Cold-Formed Channels and Z-Shapes		
301	0 - 5.75 kg/m - 0-3m	tonne	
304	> 5.75 kg/m - 0-3m	tonne	
320	Sag Rods - specify diameter and finish	tonne	
	Connection Materials and Welding		
401	Welded Plates - Gusset Plates, Wrap Plates, Shear Tabs	tonne	
402	Welded Plates - Moment Plates	tonne	
403	Welded Plates - End Plates, Clip Angles	tonne	
404	Welded Plates - Base/Cap Plates	tonne	
405	Welded Plates - Stiffeners Under W310	tonne	
406	Welded Plates - Stiffeners W360 to W460	tonne	
407	Welded Plates - Stiffeners W460 to W610	tonne	
408	Welded Plates - Web Doubler Plates	tonne	
409	Welded Plates - Shop-Welded Lifting Lugs	tonne	
410	Welded Plates - Bolted Lifting Lugs	tonne	
411	Loose Plates - Field installed	tonne	
412	Prepared Groove Welds	cm^3	
413	Seal Welding	cm	
414	Welded Shear Studs	ea	

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C2 (Cont'd)

	Miscellaneous		
501	Stair Stringers	tonne	
502	Shop Assembled Stairs - Stringers and Bolted Treads	tonne	
503	Ladders (without safety cage)	tonne	
504	Ladder (with safety cage)	tonne	
505	Checkerplate: 6 mm thick - specify installation location and method	tonne	Specify thickness, installation location, and method
507	Handrail (straight)	tonne	
508	Handrail (sloped)	tonne	
509	Handrail (circular)	tonne	
510	Safety gates: Premanufactured	Ea	
511	Safety gates: Steel Fabricated	Ea	
	Grating and Treads		
601	Stair treads (specify Bearing Bar Size, tread size surface type, finish)	Ea	
603	Grating (specify Bearing Bar Size, tread size surface type, finish)	m^2	Includes banding, kickplate, and fasteners. Details required.
605	Cold-Formed Walkway Channels	m	
606	Cold-Formed Walkway Channel Fasteners	Ea	
	Welded Frames (2 or more shop-welded framing members)		
701	Members - 0 - 15 kg/m	tonne	
702	Members - 16 - 30 kg/m	tonne	
703	Members - 31 - 60 kg/m	tonne	
704	Members - 61 - 90 kg/m	tonne	
705	Members - 90 - 155 kg/m	tonne	

APPENDIX C

A Suggested Format for Price-per-Unit Contracts

Category List C2 (Cont'd)

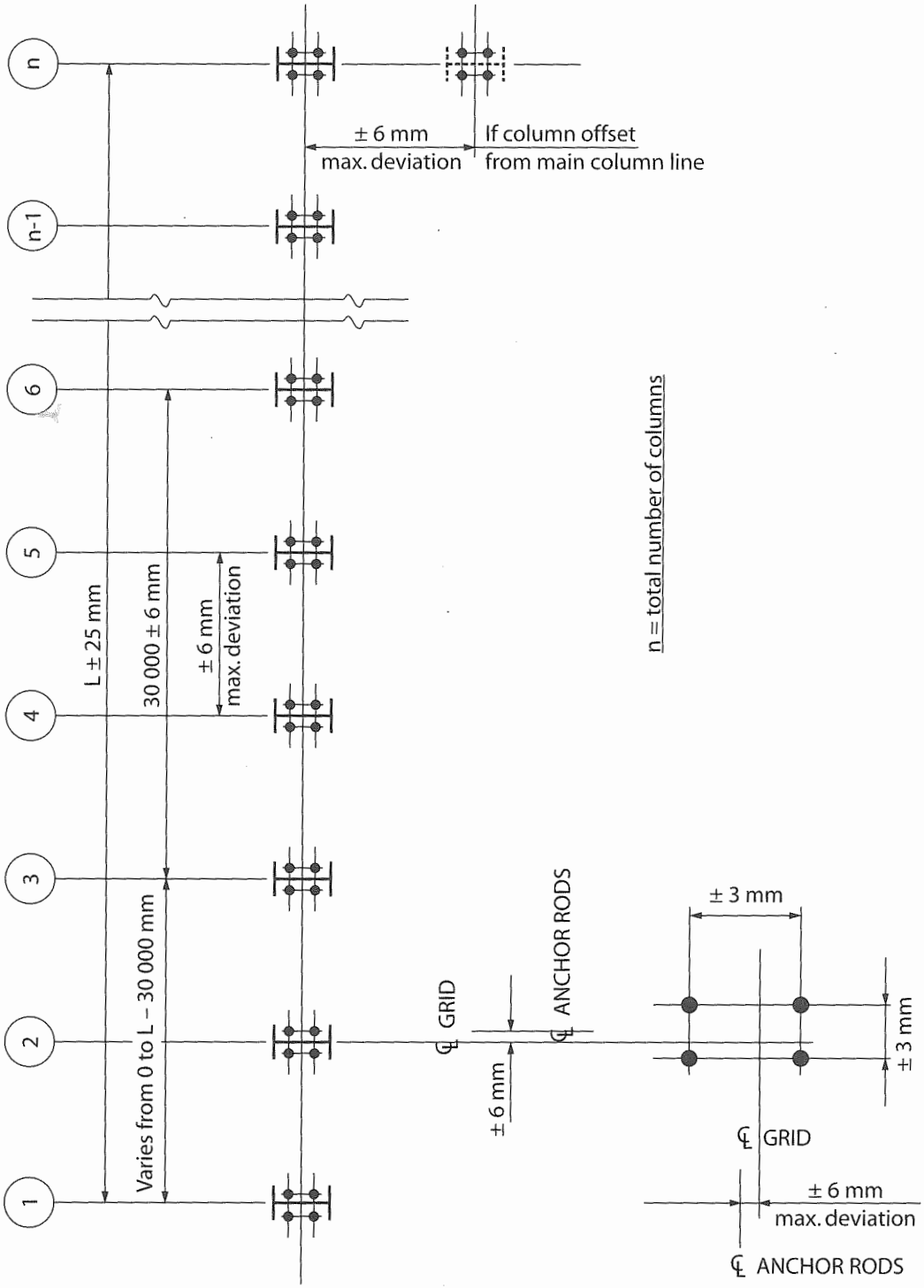
	Bolts		
801	A307 16 mm (5/8) dia. (Black) or 10mm (3/8) dia. (Plated) x length	Ea / tonne	
802	A325 Bolt (Black): 20 mm (3/4) dia. x length	Ea / tonne	
803	A325 Bolt (Black): 22 mm (7/8) dia. x length	Ea / tonne	
804	A325 Bolt (Black): 25 mm (1) dia. x length	Ea / tonne	
805	A490 Bolt (Black): 32 mm (1 1/4) dia. x length	Ea / tonne	
806	B307 (Button Head): 16 mm (5/8) dia. x length	Ea / tonne	
	Hourly Rates for Extra Work		
	Extra Engineering Design	hour	
	Extra Drafting Labour	hour	
	Extra Shop Labour	hour	
	Extra Field Labour	hour	
	Extra Administration Labour	hour	

Note:

This Code of Standard Practice for Structural Steel (in PDF format) and the above Category Lists C1 and C2 (in Excel format) may be downloaded from the CISC website at this link:

www.cisc-icca.ca/solutions-centre/publications/publications

APPENDIX D
Tolerances on Anchor Rod Placement



APPENDIX E

Conversion of SI Units to Imperial Units

When Imperial units are used in contract documents, unless otherwise stipulated, the SI units used in the CISC Code of Standard Practice for Structural Steel shall be replaced by the Imperial units shown, for the clause as noted.

Clause 3.5 (a). Unit Weight. The unit weight of steel is assumed to be 0.2833 pounds per cubic inch.

For other clauses, the standard conversion factors (for length, mass, etc.) stipulated in the CISC Handbook should be used.

Note: Imperial projects should be entirely in the imperial designation including shape sizes. Metric projects should be entirely in the SI designation, including shape sizes. Units should not be intermixed on the same project.

APPENDIX F

Miscellaneous Steel

Unless otherwise specified in the tender documents, the following items are considered miscellaneous steel of ferrous metal only, fabricated from 2.0 mm (14 ga.) and more of metal, including galvanizing, cadmium and chrome plating, but not stainless steel and cast iron items. This list of items is to be read in conjunction with Clause 2.1 Structural Steel and Clause 2.3 Items Supplied by Others, and shall include all steel items not included in Clauses 2.1 and 2.3, unless specified otherwise.

Access doors and frames — except trade-name items and those required for servicing mechanical and electrical equipment.

Angles and channel frames for doors and wall openings — drilling and tapping to be specified as being done by Others.

Benches and brackets.

Bollards, bumper posts and rails

Bolts — only includes those bolts and anchors required for anchoring miscellaneous steel supplied under this list.

Burglar/security bars.

Clothes line poles, custom-fabricated types only.

Coat rods, custom-fabricated types only.

Corner protection angles.

Expansion joint angles, plates custom-fabricated, etc., including types made from steel, or a combination of steel and non-ferrous metal.

Fabricated convector frames and enclosures.

Fabricated items where clearly detailed or specified and made from 2.0 mm (14 ga.) and heavier steel, except where included in another division.

Fabricated steel framing for curtain walls and storefronts where not detailed on structural drawings and not enclosed by architectural metal.

Fabricated wire mesh and expanded metal partitions and screens.

Fire escapes.

Flag poles — steel custom-fabricated. (Excluding hardware)

(Custom-fabricated) Footscrapers, mud and foot grilles, including pans, but less drains.

Frames, grating and plate covers for manholes, catch basins, sumps, trenches, hatches, pits, etc., except cast iron, frames and covers and trade-name floor and roof drains.

Gates, grilles, grillwork and louvres, excluding baked enamel or when forming part of mechanical system.

Grating-type floors and catwalks — excluding those forming part of mechanical system.

Handrails, balusters and any metal brackets attached to steel rail including plastic cover, excluding steel handrails forming part of structural steel framing.

Joist hangers, custom-fabricated types only.

Joist strap anchors.

Lintels, unless shown on structural drawings.

Mat recess frames, custom-fabricated types only.

Mobile chalk and tackboard frames, custom-fabricated types only.

Monorail beams of standard shapes, excluding trade-name items, unless shown on structural drawings.

Shop drawings and/or erection diagrams.

Shop preparation and/or priming.

Sleeves, if specified, except for mechanical and electrical division.

Stair nosings, custom-fabricated types only.

Steel ladders and ladder rungs not forming part of Structural Steel or mechanical work.

Steel stairs and landings not forming part of Structural Steel.

Table and counter legs, frames and brackets, custom-fabricated types only.

Thresholds and sills, custom-fabricated types only.

Vanity and valance brackets, custom-fabricated types only.

Weatherbars — steel.

Miscellaneous Steel Items Excluded

Bases and supports for mechanical and electrical equipment where detailed on mechanical or electrical drawings.

Bolts other than for anchoring items of miscellaneous steel.

Cast iron frames and covers for manhole and catch basins.

Chain link and woven wire mesh.

Glulam connections and anchorages.

Joist hangers, trade-name types.

Metal cladding and covering, less than 2.0 mm (14 ga.).

Precast concrete connections and anchorages in building structure.

Reinforcing steel or mesh.

Roof and floor hatches when trade-name items.

Sheet metal items, steel decking and siding and their attachments, closures, etc., less than 2.0 mm (14 ga.).

Shoring under composite floors and stub-girders.

Steel reinforcement for architectural metal storefronts, curtain walls and windows.

Steel stacks.

Stone anchors.

Stud shear connectors when used with steel deck.

Temporary bracing for other trades.

Thimbles and breeching, also mechanical fire dampers.

Window and area wells.

When the miscellaneous steel fabricator erects miscellaneous steel, all material required for temporary and/or permanent connections of the component parts of the miscellaneous steel shall be supplied.

APPENDIX G

A Suggested Format for a

Monthly Progress Payment Claim Form

MONTHLY PROGRESS CLAIM FORM

FIRM NAME: _____

PROJECT: _____

CONTRACT NO: _____

PROGRESS CLAIM NO: _____

DATE: _____

ITEM	ORIGINAL BASE CONTRACT	APPROVED CHANGES TO DATE	REVISED BASE CONTRACT	PROGRESS TO DATE	PREVIOUS AMOUNT CLAIMED	THIS PROGRESS CLAIM	% COMPLETE
1. ENGINEERING & DETAILING							
2. RAW MATERIALS IN YARD							
3. FABRICATION							
4. FREIGHT TO SITE							
5. ERECTION							
6. PLUMB / BOLT / CLEANUP							
7. TOTAL GROSS AMOUNT							
8. HOLDBACK _____%							
9. NET AMOUNT							
10. APPLICABLE TAX _____% OF LINE 9							
11. TOTAL AMOUNT DUE							
APPROVED CHANGE ORDER(S) TO DATE: _____							

APPENDIX H

Suggested Terms for Progress Invoicing and Substantial Performance

H1. Progress Invoicing

Monthly Progress Payments shall be based on the percentage completed of each agreed progress payment criteria during the subject billing period. Suggested progress payment criteria include:

a) Shop Details and/or Erection Diagrams submitted for review.
b) Raw materials received at the fabricators plant.
c) Fabrication of materials.
d) Release for shipment, or shipment to site, as applicable.
e) Erection of materials.
f) Finishing of erected steel Work

H2. Substantial Performance and Statutory Holdback

a) Unless stated otherwise in the Contract, substantial completion criteria and release of statutory holdback shall conform to the requirements of standard construction contracts approved by the Canadian Construction Documents Committee or the Canadian Construction Association, and the governing provincial lien legislation.

b) Contracts for supply only of structural or miscellaneous steel may not be subject to statutory holdback in accordance with the governing provincial lien acts.

c) Substantial completion of Work is be directly related to the Work of the steel Fabricator or Erector, unless stated otherwise in the Contract.

APPENDIX I

Architecturally Exposed Structural Steel (AESS)

I1. Scope and Requirements

I1.1 General Requirements. When members are specifically designated as "Architecturally Exposed Structural Steel'' or "AESS'' in the Contract Documents, the requirements in Sections 1 through 7 shall apply as modified by this Appendix. AESS members or components shall be fabricated and erected with the care and dimensional tolerances that are stipulated in Sections I2 through I5.

I1.2 Definition of Categories. Categories are listed in the AESS Matrix shown in Table I1, where each Category is represented by a set of Characteristics. The following Categories shall be used when referring to AESS:

AESS 1: Basic Elements

Suitable for "basic" elements which require enhanced workmanship.

AESS 2: Feature Elements Viewed at a Distance > 6 m

Suitable for "feature" elements viewed at a distance greater than six metres. The process involves basically good fabrication practices with enhanced treatment of weld, connection and fabrication detail, tolerances for gaps, and copes.

AESS 3: Feature Elements Viewed at a Distance ≤ 6 m

Suitable for "feature" elements, where the designer is comfortable allowing the viewer to see the art of metalworking. Welds are generally smooth but visible; some grind marks are acceptable. Tolerances are tighter than normal standards. The structure is normally viewed closer than six metres and is frequently subject to touching by the public.

AESS 4: Showcase Elements

Suitable for "showcase or dominant" elements, where the designer intends the form to be the only feature showing in an element. All welds are ground, and filled edges are ground square and true. All surfaces are sanded/filled. Tolerances of fabricated forms are more stringent – generally one-half of the standard tolerance. All surfaces are to be "glove" smooth.

AESS C: Custom Elements

Suitable for elements which require a different set of Characteristics than specified in Categories 1, 2, 3 or 4.

I1.3 Additional Information. The following additional information shall be provided in the Contract Documents when AESS is specified:

a) Specific identification of members or components that are AESS using the AESS Categories listed in I1.2. Refer to Table I1;

b) Fabrication and/or erection tolerances that are to be more restrictive than provided for in this Appendix;

c) For Categories AESS 2, 3 and 4, requirements, if any, of a visual sample or first-off component for inspection and acceptance standards prior to the start of fabrication;

d) For Category AESS C, the AESS Matrix included in Table I1 shall be used to specify the required treatment of the element.

I2. Shop Detail, Arrangement and Erection Drawings

I2.1 Identification. All members designated as AESS members are to be clearly identified with a Category, either AESS 1, 2, 3, 4 or C, on all shop detail, arrangement and erection drawings.

I2.2 Variations. Any variations from the AESS Categories listed must be clearly noted. These variations could include machined surfaces, locally abraded surfaces, and forgings. In addition:

a) If a distinction is to be made between different surfaces or parts of members, the transition line/plane must be clearly identified/defined on the shop detail, arrangement and erection drawings;

b) Tack welds, temporary braces and fixtures used in fabrication are to be indicated on shop drawings;

c) All architecturally sensitive connection details will be submitted for approval to the Architect/Engineer prior to completion of shop detail drawings.

I3. Fabrication

I3.1 General Fabrication. The Fabricator is to take special care in handling the steel to avoid marking or distorting the steel members.

a) All slings will be nylon-type or chains with softeners, or wire rope with softeners.

b) Care shall be taken to minimize damage to any shop paint or coating.

c) If temporary braces or fixtures are required during fabrication or shipment, or to facilitate erection, care must be taken to avoid and/or repair any blemishes or unsightly surfaces resulting from the use or removal of such temporary elements.

d) Tack welds shall be ground smooth.

I3.2 Unfinished, Reused or Weathering Steel. Members fabricated of unfinished, reused or weathering steel that are to be AESS may still have erection marks, painted marks or other marks on surfaces in the completed structure. Special requirements shall be specified as Category AESS C.

I3.3 Tolerances for Rolled Shapes. The permissible tolerances for depth, width, out-of-square, camber and sweep of rolled shapes shall be as specified in CSA G40.20/21 and ASTM A6. The following exceptions apply:

a) For Categories AESS 3 and 4: the matching of abutting cross-sections shall be required;

b) For Categories AESS 2, 3 and 4: the as-fabricated straightness tolerance of a member is one-half of the standard camber and sweep tolerance in CSA G40.20/21.

I3.4 Tolerances for Built-up Members. The tolerance on overall section dimensions of members made up of plates, bars and shapes by welding is limited to the accumulation of permissible tolerances of the component parts as provided by CSA W59 and ASTM A6. For Categories AESS 2, 3 and 4, the as-fabricated straightness tolerance for the built-up member is one-half of the standard camber and sweep tolerances in CSA W59.

I3.5 Joints. For Categories AESS 3 and 4, all copes, miters and butt cuts in surfaces exposed to view are made with uniform gaps, if shown to be open-joint, or in uniform contact if shown without gap.

I3.6 Surface Appearance. For Categories AESS 1, 2 and 3, the quality surface as delivered by the mills will be acceptable. For Category AESS 4, the steel surface imperfections should be filled and sanded.

I3.7 Welds. For corrosive environments, all joints should be seal-welded. In addition:

a) For Categories AESS 1, 2 and 3, a smooth uniform weld will be acceptable. For Category AESS 4, the weld will be contoured and blended.

b) For Categories AESS 1, 2, 3 and 4, all weld spatter is to be avoided/removed where exposed to view.

c) For Categories AESS 1 and 2, weld projection up to 2 mm is acceptable for butt and plug-welded joints. For Categories AESS 3 and 4, welds will be ground smooth/filled.

I3.8 Weld Show-through. It is recognized that the degree of weld show-through, which is any visual indication of the presence of a weld or welds on the opposite surface from the viewer, is a function of weld size and material thickness.

a) For Categories AESS 1, 2 and 3, the members or components will be acceptable as produced.

b) For Category AESS 4, the fabricator shall minimize the weld show-through.

I3.9 Surface Preparation for Painting. Unless otherwise specified in the Contract Documents, the Fabricator will clean AESS members to meet the requirement of SSPC-SP 6 "Commercial Blast Cleaning" (sandblast or shotblast). Prior to blast cleaning:

a) Any deposits of grease or oil are to be removed by solvent cleaning, SSPC-SP 1;

b) Weld spatter, slivers and surface discontinuities are to be removed;

c) Sharp edges resulting from flame cutting, grinding and especially shearing are to be softened.

I3.10 Hollow Structural Sections (HSS) Seams

a) For Categories AESS 1 and 2, seams of hollow structural sections shall be acceptable as produced.

b) For Category AESS 3, seams shall be oriented away from view or as indicated in the Contract Documents.

c) For Category AESS 4, seams shall be treated so that they are not apparent.

I4. Delivery of Materials

I4.1 General Delivery. The Fabricator shall use special care to avoid bending, twisting or otherwise distorting the Structural Steel. All tie-downs on loads will be either nylon strap or chains with softeners to avoid damage to edges and surfaces of members.

I4.2 Standard of Acceptance. The standard for acceptance of delivered and erected members shall be equivalent to the standard employed at fabrication.

I5. Erection

I5.1 General Erection. The Erector shall use special care in unloading, handling and erecting the AESS to avoid marking or distorting the AESS. The Erector must plan and execute all operations in a manner that allows the architectural appearance of the structure to be maintained.

a) All slings will be nylon-strap or chains with softeners.

b) Care shall be taken to minimize damage to any shop paint or coating.

c) If temporary braces or fixtures are required to facilitate erection, care must be taken to avoid and/or repair any blemishes or unsightly surfaces resulting from the use or removal of such temporary elements.

d) Tack welds shall be ground smooth and holes shall be filled with weld metal or body filler and smoothed by grinding or filling to the standards applicable to the shop fabrication of the materials.

e) All backing bars shall be removed and ground smooth.

f) All bolt heads in connections shall be on the same side, as specified, and consistent from one connection to another.

I5.2 Erection Tolerances. Unless otherwise specified in the Contract Documents, members and components are plumbed, levelled and aligned to a tolerance equal to that permitted for structural steel.

I5.3 Adjustable Connections. When more stringent tolerances are specifically required for erecting AESS, the Owner's plans shall specify/allow adjustable connections between AESS and adjoining structural elements, in order to enable the Erector to adjust and/or specify the method for achieving the desired dimensions. Adjustment details proposed by the Erector shall be submitted to the Architect and Engineer for review.

TABLE I1 - AESS Category Matrix

	Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
ID	*Characteristics*	*Custom Elements*	*Showcase Elements*	*Viewed at a distance ≤ 6 m*	*Viewed at a distance > 6 m*	*Basic Elements*	*CSA S16*
1.1	Surface preparation to SSPC-SP 6		√	√	√	√	
1.2	Sharp edges ground smooth		√	√	√	√	
1.3	Continuous weld appearance		√	√	√	√	
1.4	Standard structural bolts		√	√	√	√	
1.5	Weld spatter removed		√	√	√	√	
2.1	Visual samples		optional	optional	optional		
2.2	One-half standard fabrication tolerances		√	√	√		
2.3	Fabrication marks not apparent		√	√	√		
2.4	Welds uniform and smooth		√	√	√		
3.1	Mill marks removed		√	√			
3.2	Butt and plug welds ground smooth and filled		√	√			
3.3	HSS weld seam oriented for reduced visibility		√	√			
3.4	Cross-sectional abutting surfaces aligned		√	√			
3.5	Joint gap tolerances minimized		√	√			
3.6	All welded connections		optional	optional			
4.1	HSS seam not apparent		√				
4.2	Welds contoured and blended		√				
4.3	Surfaces filled and sanded		√				
4.4	Weld show-through minimized		√				
C.1							
C.2							
C.3							
C.4							
C.5							

TABLE I1 - AESS Category Matrix (Cont'd)

	Notes
1.1	Prior to blast cleaning, any deposits of grease or oil are to be removed by solvent cleaning, SSPC-SP 1.
1.2	Rough surfaces are to be deburred and ground smooth. Sharp edges resulting from flame cutting, grinding and especially shearing are to be softened.
1.3	Intermittent welds are made continuous, either with additional welding, caulking or body filler. For corrosive environments, all joints should be seal welded. Seams of hollow structural sections shall be acceptable as produced.
1.4	All bolt heads in connections shall be on the same side, as specified, and consistent from one connection to another.
1.5	Weld spatter, slivers and surface discontinuities are to be removed. Weld projection up to 2 mm is acceptable for butt and plug-welded joints.
2.1	Visual samples are either a 3-D rendering, a physical sample, a first-off inspection, a scaled mock-up or a full-scale mock-up, as specified in Contract Documents.
2.2	These tolerances are required to be one-half of those of standard structural steel as specified in CSA S16.
2.3	Members marked with specific numbers during the fabrication and erection processes are not to be visible.
2.4	—
3.1	All mill marks are not to be visible in the finished product.
3.2	Caulking or body filler is acceptable.
3.3	Seams shall be oriented away from view or as indicated in the Contract Documents.
3.4	The matching of abutting cross-sections shall be required.
3.5	This characteristic is similar to 2.2 above. A clear distance of 3 mm between abutting members is required.
3.6	Hidden bolts may be considered.
4.1	HSS seams shall be treated so that they are not apparent.
4.2	In addition to a contoured and blended appearance, welded transitions between members are also required to be contoured and blended.
4.3	Steel surface imperfections should be filled and sanded.
4.4	The back face of a welded element caused by the welding process can be minimized by hand grinding the back side of the weld. The degree of weld show-through is a function of weld size and material.
C.	Additional characteristics may be added for custom elements.

APPENDIX J

Building Information Modelling

This Appendix is intended to facilitate the understanding and use of digital modelling technology in the design and construction of Steel Structures.

J1. General Provisions

J1.1 Scope

The provisions in this Appendix shall apply when the Contract Documents indicate that a three-dimensional digital Building Information Model (BIM) or Digital/Electronic Model replaces Contract Documents and is to be used as the primary means of designing, representing, and exchanging Structural Steel data for the project. In this case, references to the Design Drawings shall apply to the Design Model, and references to Fabrication and Erection Documents shall apply to the Manufacturing Model.

If the primary means of project communication reverts from a model-based (electronic) system to a paper-based system, the requirements of this Appendix are no longer applicable.

J1.2 Definitions

See Section 1.2 of the CISC Code of Standard Practice for all definitions related to this Appendix.

J2. Supplementary Technical Standards

The following references are provided as a guide to assist in developing a BIM Execution Plan with reference to the Contract Documents. The provisions of other standards shall be applicable if called for in the Project Tender Documents and Construction Specifications.

BIM Execution Plan – *Project Execution Planning Guide V2.0 Released July 2010*

https://bim.psu.edu/

LOD – *2014 LOD Specification*

https://bimforum.org/lod/

LOD Matrix (*also referred to as a model element table*) – AIA Document E203 - 2013

http://www4.fm.virginia.edu/fpc/ContractAdmin/ProfSvcs/BIMAIASample.pdf

Naming Conventions – *Naming Convention for Structural Steel Products for Use in Electronic Data Interchange (EDI). AISC Document June 25, 2001*

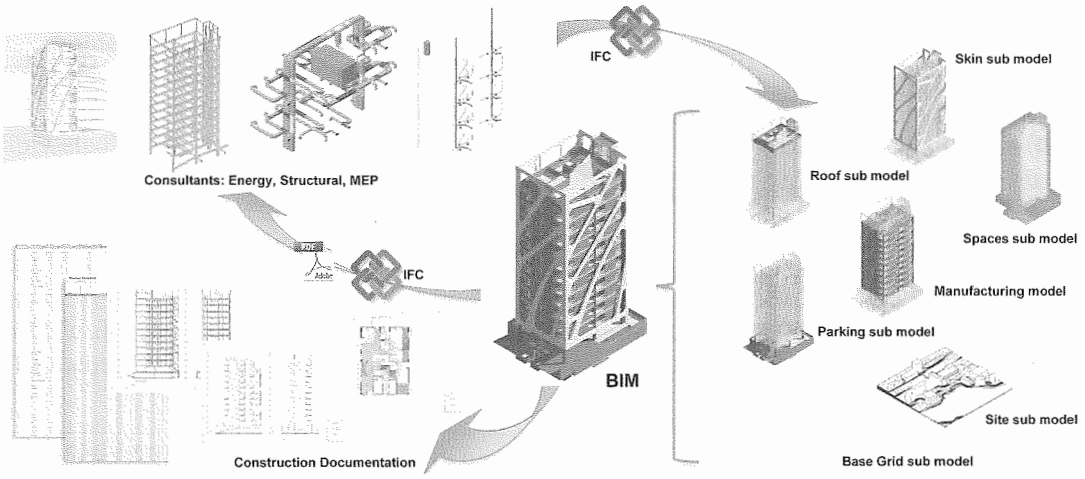
https://aisc.org/WorkArea/showcontent.aspx?id=6444

J3. File Format

The Industry Foundation Class Model should be used, unless otherwise agreed, as the Building Information Model for structural steel. The Industry Foundation Class model for Structural Steel may exist solely as the project's BIM or may be integrated into a multi-disciplinary BIM for projects adopting greater digital model design application.

Refer to the Electronic Data Interchange Project Flowchart (Figure J1) for an example of this interoperability. The figure demonstrates how the BIM file serves several functions. It acts as

the repository for project information developed in stand-alone external software platforms such as the manufacturing model. It also acts as a source file from which contract documentation and specific model data can be extracted for further analysis.



Electronic Data Interchange Project Flowchart

Figure J1

Note: Images taken from www.vectorworks.net

J4. Content and Purpose of the BIM Files

In addition to the requirements in Clause 4 related to Contract Documents, the following requirements shall apply to the BIM file.

J4.1 The BIM file is intended to:

a) Govern over all other forms of information, including drawings, sketches, etc., unless specifically noted otherwise in the Construction Documents.

b) Include all steel elements (primary and secondary structural), as well as any other entities required for strength and stability of the completely erected structure.

c) Include entities that fully define each steel element, and the extent of detailing of each element, as would be recorded on an equivalent set of Structural Design Documents (see Clause 4.1.2).

d) Contain Analysis Model data so as to include load calculations as indicated in the Construction Specifications referencing jurisdictional codes.

e) Conform to the required Level of Development (LOD). See Figures J2, J3, and J4.

f) Provide a common reference point and datum (0, 0, 0).

g) Contain all necessary information to comply with downstream user requirements (i.e. design loads, member sizes, dimensions, etc.).

J5. Project Governance

For all BIM projects, a BIM Administrator will be assigned and provided by Others.

J5.1 The BIM Administrator will ensure that the BIM Execution Plan is followed. BIM Administrator responsibilities are intended to include the following:

a) Define control of the BIM by providing appropriate access privileges (read, write, etc.) to all relevant parties.

b) Maintain the security of the BIM.

c) Guard against data loss of the BIM.

d) Be responsible for updates and revisions to the BIM as they occur, and archive all versions with appropriate annotations.

e) Inform all involved parties regarding changes to the BIM.

J6. Usability and Protocol

J6.1 In addition to the requirements in Clause 5 related to Fabrication and Erection Documents, the following requirements shall apply:

a) In the event of a conflict between the BIM and Design Documents, the BIM Execution Plan will determine which document governs. In the absence of this clarification in the BIM Execution Plan, the BIM file shall govern.

b) The responsibility for the development and accuracy of the information added to the BIM file shall be defined in the Contract Documents. In the absence of such terms regarding the information added by the Fabricator (via sharing of the manufacturing model) to the BIM in the Construction Documents, the responsibility will belong to the Fabricator in accordance with the appropriate LOD definition. For clarification related to instructions provided to the Fabricator by other project stakeholders, see LOD Section J8 of this Appendix.

c) During the development of the Manufacturing Model, any relocation of, or adjustments to, members will only be done with approval by the Engineer of Record.

d) The Fabricator and Erector shall accept the use of the Manufacturing Model and the BIM under the same conditions as set forth in Clause 4.3.1, except as modified in J7.

J7. Review

Review of the Manufacturing Model by the Engineer of Record may replace the review of the actual Fabrication and Erection Documents. For this method to be effective, a system must be in place to capture review comments and action items, and to complete the review, correction and final release of the Manufacturing Model for fabrication of structural steel. The versions of the model shall be tracked with review comments permanently attached to the versions of the model to the same extent as such data is maintained with conventional hard copy approvals. The Industry Foundation Class Standard provides this level of tracking.

J7.1 When a review of the detailed material is to be done by using the Manufacturing Model, the version of the submitted model shall be identified. Comments attached to the individual elements as specified in the BIM Execution Plan shall be used to annotate the Manufacturing

Model. The Fabricator will issue the revised Manufacturing Model for review, and the version of the model submitted will be tracked as previously defined.

J8. Level of Development (LOD)

It is important to identify the extent of information that will be provided in the BIM by each stakeholder. The LOD matrix provides a mechanism for defining these responsibilities and commitments. Prior to the development of the LOD matrix specific to any given project, it will be assumed that the detailer will only be responsible for providing information up to the "as-fabricated" state, commonly referred to as LOD 400. Changes beyond the base scope of Work are to be inputted into the BIM by the Owner, unless otherwise agreed to as part of the change management process.

The LOD matrix will determine which project team member is responsible for developing the model to the associated LOD status by assigning a Model Element Author (MEA) for each specific development status number for each line item. An example table taken from AIA document E202 is provided below for general reference.

§ 4.3 Model Element Table *Identify (1) the LOD required for each Model Element at the end of each phase, and (2) the Model Element Author (MEA) responsible for developing the Model Element to the LOD identified.* *Insert abbreviations for each MEA identified in the table below, such as "A – Architect," or "C – Contractor."* *NOTE: LODs must be adapted for the unique characteristics of each Project.*					Conceptualization		Criteria Design		Detailed Design		Implementation Documents		Construction				Note Number (See 4.4)
Model Elements Utilizing CSI UniFormat™					LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	
A SUBSTRUCTURE	A10	Foundations	A1010	Standard Foundations	100		200		300		400		500				
			A1020	Special Foundations	100		100		300		400		500				
			A1030	Slab on Grade	100		200		300		400		500				
	A20	Basement Construction	A2010	Basement Excavation	100		200		300		300		500				
			A2020	Basement Walls	100		200		300		400		500				
B SHELL	B10	Superstructure	B1010	Floor Construction	100		200		300		300		500				
			B1020	Roof Construction	100		200		300		300		500				

LOD Matrix

Figure J2

LOD definitions are described as follows.

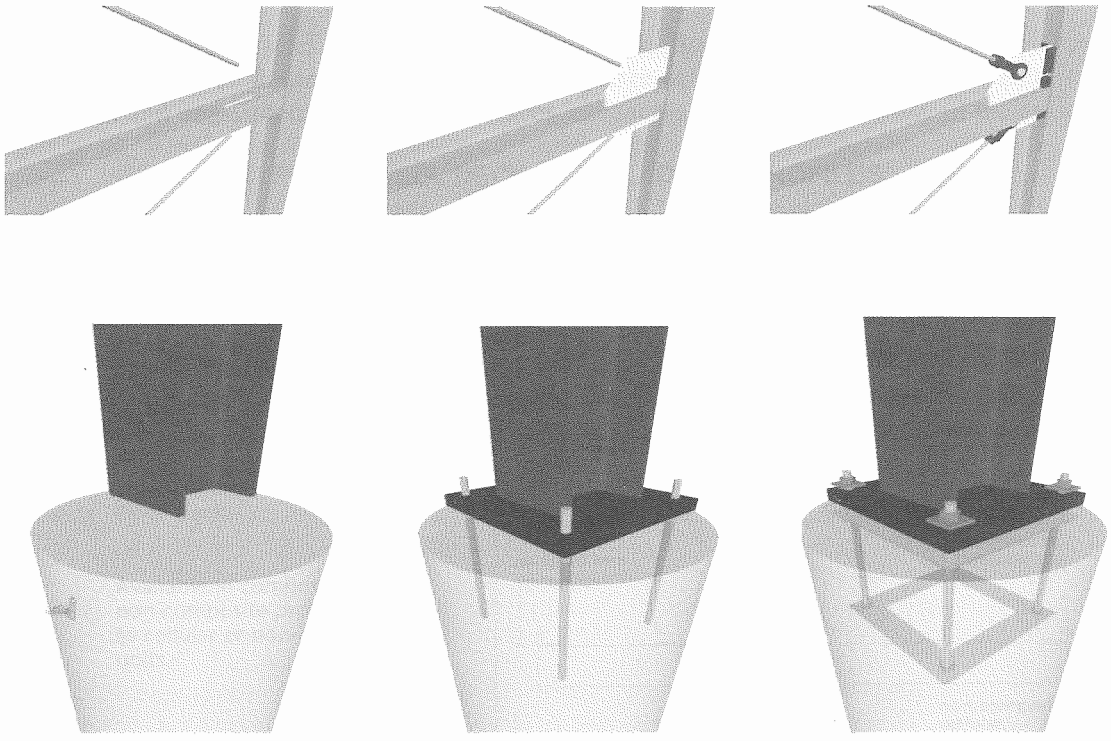
Level of Development (LOD) Descriptions	
LOD 100	The Model Element may be graphically represented in the Model with a symbol or other generic representation but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.
LOD 200	The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.
LOD 300	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.
LOD 350	The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.
LOD 400	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element.
LOD 500	The Model Element is a field-verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

LOD Descriptions

Figure J3

Note: The definitions for LOD 100, 200, 300, 400, and 500 included in this Specification represent the updated language that appears in the AIA's most recent BIM protocol document, G202–2013, Building Information Modelling Protocol Form. *The LOD 100, 200, 300, 400 and 500 definitions are produced by the AIA and have been used by permission. LOD 350 was developed by the BIMForum working group and is copyright to the BIMForum and the AIA.*

Graphical representations of the LOD descriptions are provided for visual reference.



LOD 300 **LOD 350** **LOD 400**

LOD Diagram (Example)

Figure J4

Note: Images taken from BIMFORUM Level of Development Specification 2013.

STRUCTURAL SHEET STEEL PRODUCTS

General

Structural sheet steel products such as roof deck, floor deck and cladding complement the structural steel frame of a building. These large-surface elements often perform both structural and non-structural functions, thereby enhancing the overall economy of the design.

TYPICAL STEEL DECK AND CLADDING PROFILES

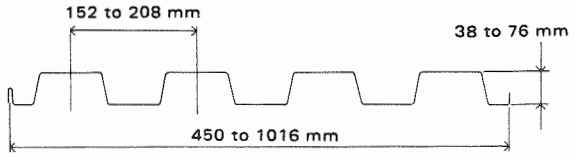
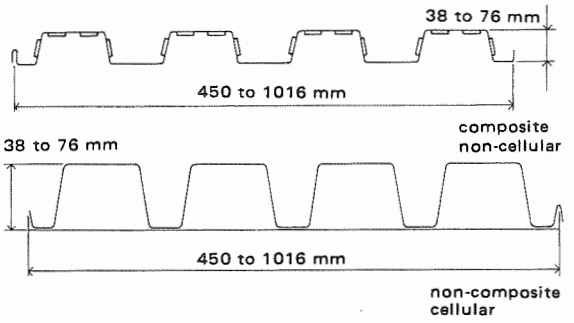
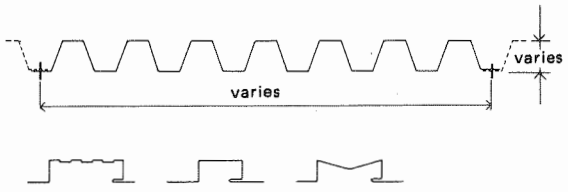
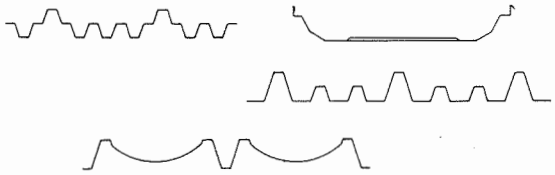
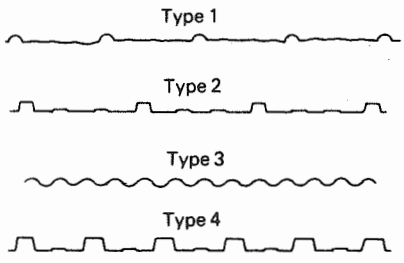
Roof Deck Can be supplied perforated for acoustical applications.	
Floor Deck Available in composite and non-composite profiles and as cellular or non-cellular units.	
Architectural Cladding Available in various profiles, widths, coatings and colours.	
Steel Building Systems Cladding Available in various profiles, widths, coatings and colours	
Farm Building Cladding Available in various profiles, widths, coatings and colours	

Figure 1: Typical Cladding Profiles

Figure 1 is for general information only, and manufacturers may produce additional profiles which are not represented by any of the types shown.

Many of the sheet steel products used in Canada are supplied by members of the Canadian Sheet Steel Building Institute, a national association of steel producers, zinc producers, coil coaters, fastener manufacturers and fabricators of steel building products, steel building systems and lightweight steel framing components. The Institute promotes the use of sheet steel in building construction by encouraging good design, pleasing form and greater economy.

Sheet steel materials for building construction are metallic coated (zinc or aluminum-zinc alloy) and can be prefinished for extra corrosion protection and aesthetics. Consult fabricators' catalogs for details of available products, profiles, widths, lengths, thicknesses, load capacities and other characteristics.

CSSBI PUBLICATIONS

CSSBI publications include industry product standards, informational bulletins and special publications as well as non-technical promotional material. A selection of current publications is listed below.

CSSBI Standards

Steel Roof Deck – covers design, fabrication and erection of steel roof deck with flutes not more than 200 mm on centre and a nominal 77 mm maximum profile depth, intended for use with built-up roofing or other suitable weather-resistant cover on top of the deck (CSSBI 10M).

Composite Steel Deck – covers design, fabrication and erection of composite steel deck with a nominal 77 mm maximum profile depth, intended for use with a concrete cover slab on top of the deck to create a composite slab (CSSBI 12M).

Sheet Steel Cladding for Architectural, Industrial and Commercial Building Applications – covers design, fabrication and erection of weather-tight wall and roof cladding made from metallic coated, prefinished sheet steel for use on buildings with low internal humidity (CSSBI 20M).

Steel Building Systems – covers the design, fabrication and erection of steel building systems (SBS). Includes definitions, classification of SBS by type, checklist of items normally furnished, criteria for load combinations, design standards, and certification by a registered engineer (CSSBI 30M).

Steel Farm Roofing and Siding – covers the manufacture, load carrying capacity, handling and installation of sheet steel cladding intended for application to walls and/or roofs of farm buildings (CSSBI 21M).

Bulletins and Special Publications

Criteria for the Testing of Composite Slabs – provides the criteria for conducting a series of shear-bond tests necessary to determine the structural capacity of a composite slab (CSSBI S2).

Criteria for the Design of Composite Slabs – contains design criteria, based on limit states design, for composite slabs made of a structural concrete placed permanently over a composite steel deck (CSSBI S3).

Design of Steel Deck Diaphragms – offers a simple and practical approach to the design of steel deck diaphragms supported by horizontal steel framing (CSSBI B13).

Lightweight Steel Framing Design Manual – shows through examples how to design lightweight steel framing structural systems. Detailed calculations are shown for curtain walls, infill walls, and axial load bearing systems as well as all connections (CSSBI 51M).

How-To Series: Insulated Sheet Steel Wall Assemblies – describes the various stages in the selection of sheet steel wall assembly components, architectural and structural design issues, as well as building science topics and material selection (CSSBI S10).

How-To Series: Insulated Sheet Steel Roof Assemblies – describes the various stages in the selection of the sheet steel roof assembly components, architectural and structural design issues, as well as building science topics and material selection (CSSBI S11).

How-To Series: Steel Roof and Floor Deck – describes the various stages in the selection of steel deck products, the different types of deck products, structural design issues and material selection (CSSBI S15).

How-To Series: Lightgauge Steel Roofing and Siding – offers simple and practical recommendations for the selection, application and installation of lightgauge steel cladding (CSSBI S14).

Barrier Series Prefinished Sheet Steel: Product Performance & Applications – presents the features and benefits of the Barrier Series prefinished paint system for sheet steel building products in more aggressive environments (CSSBI B17).

Lightweight Steel Framing Architectural Design Guide – provides information to the architect about the uses and specification of Lightweight Steel Framing (LSF) systems, including details on design, building science, acoustic and fire ratings, as well as extensive references (CSSBI 57).

Contact CSSBI at the address below for a complete listing of publications, copies of publications, or other information concerning sheet steel in construction.

Canadian Sheet Steel Building Institute
652 Bishop St. N., Unit 2A
Cambridge, Ontario N3H 4V6
Tel (519) 650-1285
Fax (519) 650-8081
Website: www.cssbi.ca

MASS AND FORCES FOR MATERIALS

MATERIAL	Mass (kg/m^3)	Force (kN/m^3)
METALS, ALLOYS, ORES		
Aluminum	2 640	25.9
Brass	8 550	83.8
Bronze, 7.9-14% tin	8 150	79.9
Bronze, aluminum	7 700	75.5
Copper	8 910	87.4
Copper ore, pyrites	4 200	41.2
Gold	19 300	189
Iron, cast, pig	7 210	70.7
Iron, wrought	7 770	76.2
Iron, spiegel-eisen	7 500	73.5
Iron, ferro-silicon	7 000	68.6
Iron ore, hematite	5 210	51.1
Iron ore, hematite in bank	2 560-2 880	25.1-28.2
Iron ore, hematite, loose	2 080-2 560	20.4-25.1
Iron ore, limonite	3 800	37.3
Iron ore, magnetite	5 050	49.5
Iron slag	2 760	27.1
Lead	11 400	112
Lead ore, galena	7 450	73.1
Magnesium	1 790	17.6
Manganese	7 610	74.6
Manganese ore	4 150	40.7
Mercury	13 600	133
Monel	8 910	87.4
Nickel	9 050	88.8
Platinum	21 300	209
Silver	10 500	103
Steel, rolled	7 850	77.0
Tin	7 350	72.1
Tin ore, cassiterite	6 700	65.7
Zinc	7 050	69.1
Zinc ore, blende	4 050	39.7
MASONRY		
Ashlar	2 240-2 560	22.0-25.1
Brick, soft	1 760	17.3
Brick, common	2 000	19.6
Brick, pressed	2 240	22.0
Clay tile, average	961	9.42
Rubble	2 080-2 480	20.4-24.3
Concrete, cinder, haydite	1 600-1 760	15.7-17.3
Concrete, slag	2 080	20.4
Concrete, stone	2 310	22.7
Concrete, stone, reinforced	2 400	23.5
SOLID FUELS		
Coal, anthracite, piled	753-929	7.38-9.11
Coal, bituminous, piled	641-865	6.29-8.48
Coke, piled	368-513	3.61-5.03
Charcoal, piled	160-224	1.57-2.20
Peat, piled	320-416	3.14-4.08
ICE AND SNOW *		
Ice	897	8.80
Snow, dry, fresh fallen	128	1.26
Snow, dry, packed	192-400	1 .88-3.92
Snow, wet	432-641	4.24-6.29

MATERIAL	Mass (kg/m^3)	Force (kN/m^3)
TIMBER, AIR-DRY		
Birch	689	6.76
Cedar	352	3.45
Fir, Douglas, seasoned	545	5.34
Fir, Douglas, unseasoned	641	6.29
Fir, Douglas, wet	801	7.86
Fir, Douglas, glue laminated	545	5.34
Hemlock	481	4.72
Larch, tamarack	561	5.50
Larch, western	609	5.97
Maple	737	7.23
Oak, red	689	6.76
Oak, white	753	7.38
Pine, jack	481	4.72
Pine, ponderosa	513	5.03
Pine, red	449	4.40
Pine, white	416	4.08
Poplar	481	4.72
Spruce	449	4.40
For pressure treated timber add retention to mass of air-dry material.		
LIQUIDS		
Alcohol, pure	785	7.70
Gasoline	673	6.60
Oils	929	9.11
Water, fresh at 4°C (max. density)	1 000	9.81
Water, fresh at 100°C	961	9.42
Water, salt	1 030	10.1
EARTH, ETC. EXCAVATED		
Earth, wet	1 600	15.7
Earth, dry	1 200	11.8
Sand and gravel, wet	1 920	18.8
Sand and gravel, dry	1 680	16.5
VARIOUS BUILDING MATERIALS		
Cement, Portland, loose	1 510	14.8
Cement, Portland, set	2 930	28.7
Lime, gypsum, loose	849-1 030	8.33-10.1
Mortar, cement-lime, set	1 650	16.2
Quarry stone, piled	1 440-1 760	14.1-17.3
MISCELLANEOUS		
Asphaltum	1 300	12.7
Tar, bituminous	1 200	11.8
Glass, common	2 500	24.5
Glass, plate or crown	2 580	25.3
Glass, crystal	2 950	28.9
Paper	929	9.11
* *Consult building code for snow load and density.*		

DESIGN DEAD LOADS (kPa) OF MATERIALS

STEEL DECKS	
Steel deck* 38 mm deep	
(up to 0.91 mm thick)	0.10
(1.22 to 1.52 mm thick)	0.15
Steel deck* 76 mm deep (Narrow-Rib)	
(up to 0.91 mm thick)	0.15
(1.22 to 1.91mm thick)	0.30
Steel deck* 76 mm deep (Wide-Rib)	
(up to 0.91 mm thick)	0.10
(1.22 to 1.52 mm thick)	0.15
* for cellular deck, add	0.08
CONCRETE, per 100 mm	
- 2350 kg/m^3 (N.D.)	2.31
- 2000 kg/m^3 (slag aggregate)	1.96
-1850 kg/m^3 (S.L.D.)	1.82
HOLLOW CORE PRECAST (no topping)	
- 200 mm deep (N.D.)	2.60
- 300 mm deep (N.D.)	3.50
WOOD JOISTS (at 400 mm centres)	
- 38 mm x 184 mm joists	0.09
- 38 mm x 235 mm joists	0.12
- 38 mm x 286 mm joists	0.14
PLYWOOD	
- 11 mm thick	0.06
- 14 mm thick	0.08
- 19 mm thick	0.11
CHIPBOARD	
- 12.7 mm thick	0.07
- 15.9 mm thick	0.09
- 19.0 mm thick	0.11
WALLS AND CLADDING	
- Solid brick wall (concrete)	
- 100 mm thick (S.L.D.)	1.40
- 100 mm thick (N.D.)	1.90
- Hollow block (S.L.D.)	
- 100 mm thick	1.10
- 200 mm thick	1.60
- 300 mm thick	2.30
- Hollow block (N.D.)	
- 100 mm thick	1.40
- 200 mm thick	2.10
- 300 mm thick	2.90
- P.C. wall plus glazing	2.40 - 3.80
- Metal curtain wall	0.74 - 1.50
- Insulated sheet steel wall (exclude girts)	0.25 - 0.40
- 38 x 89 wood studs @ 400 mm	0.05
- Gypsum wallboard per 10 mm	0.08
- Stone veneer per 25 mm	0.40

FLOOR FINISHING	
- Vinyl, linoleum or asphalt tile	0.07
- Softwood subfloor per 10 mm	0.06
- Hardwood per 10 mm	0.08
- Carpeting	0.10
- Asphaltic concrete per 10 mm	0.23
- 20 mm Ceramic or quarry tiles on 12 mm mortar bed	0.80
- Terrazzo per 10 mm	0.24
- Mastic floor (20 mm)	0.45
ROOFING	
- 3 ply asphalt, no gravel	0.15
- 4 ply asphalt, no gravel	0.20
- 3 ply asphalt and gravel	0.27
- 4 ply asphalt and gravel	0.32
- Asphalt strip shingles	0.15
- Gypsum wallboard per 10 mm	0.08
INSULATION (per 100 mm thick)	
- Glass fibre, batts	0.05
- Glass fibre, blown	0.04
- Glass fibre, rigid	0.07
- Urethane, rigid foam	0.03
- Insulating concrete	0.06
CEILINGS	
- Gypsum wallboard per 10 mm	0.08
- Tiled ceiling & suspension system, with fixtures, average	0.20
- 20 mm plaster on lath/furring	0.40
- Sprayed fire protection, average	0.07
- Ducts/pipes/wiring allowance (average condition)	0.25
DECK-SLABS (average condition)	
- 38 mm deck with	
- 65 mm N.D. cover#	1.95
- 90 mm N.D. cover#	2.55
- 65 mm S.L.D. cover##	1.55
- 85 mm S.L.D. cover##	1.90
- 75 mm (or 76 mm) "wide-rib" deck with	
- 65 mm N.D. cover#	2.55
- 90 mm N.D. cover#	3.15
- 65 mm S.L.D. cover##	2.15
- 85 mm S.L.D. cover##	2.50
- 76 mm "narrow-rib" deck with	
- 65 mm N.D. cover#	2.20
- 90 mm N.D. cover#	2.80
- 65 mm S.L.D. cover##	1.90
- 85 mm S.L.D. cover##	2.25
# assume 2350 kg/m^3 concrete	
## assume 1850 kg/m^3 concrete	

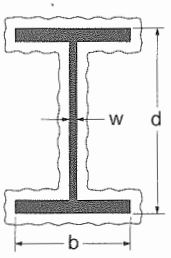
M/D Ratios

How *M/D* Ratios are Calculated

M/D ratios are used to measure the thermal mass resistance of a member under fire. Typically, the higher the *M/D* ratio, the greater the fire resistance. The numbers given in the following table were calculated by dividing the steel member mass per unit length, *M* (kg/m) by the heated perimeter, *D* (m). The resulting units are (kg/m)/m in the Metric system and (lb/ft)/in in the Imperial system.

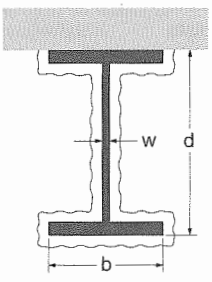
The *D* value is based on the heated perimeter following the contour of the shape, including all flange and web surfaces, and is applicable to fire protection with spray-applied fire-resistive materials. Two separate *M/D* ratios are given for each steel section: (1) one for columns based on the entire perimeter (fire exposure from all sides), and (2) one for beams which typically have the top surface of its top flange shielded from the fire, hence having one less exposed surface.

This heated perimeter (*D*) calculation corresponds to the "contour protection", as described by Gewain *et al* (2006), and is distinct from the "box protection" based on members being boxed up with gypsum board.



$D \approx 4b + 2d - 2w$

(1) Heated perimeter, *D* for steel columns



$D \approx 3b + 2d - 2w$

(2) Heated perimeter, *D* for steel beams

Note: The above formulas for the heated perimeter are approximate and do not include the flange-to-web fillets. These have been taken into account when calculating the M/D ratios given in the following pages.

Reference

GEWAIN, R.G., IWANKIW, N.R., ALFAWAKHIRI, F., AND FRATER, G. 2006. Fire Facts for Steel Buildings, Canadian Institute of Steel Construction, American Institute of Steel Construction.

M/D RATIOS FOR CONTOUR PROTECTION
W SHAPES

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column
W1100				
x499	149		2.54	
x433	130		2.21	
x390	118		2.01	
x343	104		1.77	
W1000				
x976	291		4.97	
x883	267		4.55	
x748	230		3.92	
x642	200		3.41	
x591	185		3.16	
x554	174		2.98	
x539	170		2.90	
x483	153		2.62	
x443	141		2.41	
x412	132		2.25	
x371	119		2.04	
x321	104		1.77	
x296	96.3		1.64	
W1000				
x584	199		3.40	
x494	171		2.92	
x486	169		2.88	
x438	153		2.60	
x415	146		2.49	
x393	138		2.36	
x350	124		2.11	
x314	112		1.91	
x272	97.4		1.66	
x249	89.6		1.53	
x222	80.5		1.37	
W920				
x1377	404		6.89	
x1269	373		6.37	
x1194	354		6.05	
x1077	324		5.53	
x970	296		5.05	
x787	245		4.18	
x725	228		3.89	
x656	208		3.55	
x588	188		3.21	
x537	172		2.94	
x491	159		2.71	
x449	146		2.49	
x420	137		2.33	
x390	127		2.17	
x368	120		2.05	
x344	113		1.93	

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column
W920				
x381	139		2.37	
x345	127		2.16	
x313	115		1.97	
x289	107		1.82	
x271	101		1.72	
x253	94.5		1.61	
x238	89.1		1.52	
x223	84.2		1.44	
x201	76.0		1.30	
W840				
x576	195		3.33	
x527	180		3.08	
x473	163		2.78	
x433	150		2.56	
x392	137		2.33	
x359	126		2.15	
x329	116		1.98	
x299	106		1.81	
W840				
x251	99.5		1.70	
x226	90.3		1.54	
x210	84.3		1.44	
x193	77.9		1.33	
x176	71.0		1.21	
W760				
x582	211		3.60	
x531	194		3.31	
x484	179		3.05	
x434	161		2.75	
x389	146		2.49	
x350	132		2.26	
x314	119		2.04	
x284	108		1.85	
x257	98.9		1.69	
W760				
x220	96.5		1.65	
x196	86.6		1.48	
x185	81.7		1.39	
x173	77.0		1.31	
x161	71.4		1.22	
x147	65.8		1.12	
x134	59.8		1.02	
W690				
x802	301		5.13	
x548	215		3.68	
x500	198		3.38	
x457	183		3.12	
x419	169		2.88	
x384	156		2.66	
x350	143		2.45	
x323	133		2.27	
x289	120		2.04	
x265	110		1.88	
x240	101		1.72	
x217	91.9		1.57	

M/D RATIOS FOR CONTOUR PROTECTION
W SHAPES

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.		Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column		Beam	Column	Beam	Column
W690					W460				
x192	91.3		1.56		x464	239		4.07	
x170	81.4		1.39		x421	220		3.76	
x152	73.4		1.25		x384	203		3.46	
x140	67.6		1.15		x349	186		3.18	
x125	61.1		1.04		x315	170		2.90	
					x286	156		2.66	
W610					x260	143		2.45	
x551	235		4.00		x235	131		2.23	
x498	215		3.67		x213	119		2.04	
x455	198		3.37		x193	109		1.87	
x415	183		3.12		x177	101		1.72	
x372	165		2.82		x158	90.2		1.54	
x341	152		2.60		x144	83.1		1.42	
x307	139		2.37		x128	74.2		1.27	
x285	130		2.21		x113	65.8		1.12	
x262	119		2.04						
x241	111		1.89		W460				
x217	100		1.71		x106	71.8		1.23	
x195	90.7		1.55		x97	65.9		1.12	
x174	81.3		1.39		x89	61.2		1.05	
x155	72.6		1.24		x82	56.5		0.964	
					x74	51.4		0.877	
W610									
x153	82.2		1.40		W460				
x140	75.3		1.29		x68	51.2		0.873	
x125	67.6		1.15		x60	44.8		0.764	
x113	61.6		1.05		x52	39.5		0.674	
x101	55.5		0.947						
					W410				
W610					x149	93.2		1.59	
x92	54.5		0.931		x132	83.3		1.42	
x82	48.6		0.830		x114	72.7		1.24	
					x100	63.7		1.09	
W530									
x409	194		3.31		W410				
x369	176		3.01		x85	63.9		1.09	
x332	160		2.74		x74	56.7		0.967	
x300	147		2.50		x67	51.3		0.876	
x272	134		2.29		x60	45.5		0.777	
x248	123		2.09		x54	41.2		0.703	
x219	109		1.87						
x196	98.9		1.69		W410				
x182	91.8		1.57		x46	38.9		0.663	
x165	84.1		1.43		x39	33.1		0.566	
x150	76.8		1.31						
W530									
x138	82.1		1.40						
x123	73.8		1.26						
x109	65.7		1.12						
x101	61.3		1.05						
x92	56.2		0.959						
x82	50.2		0.856						
x72	44.3		0.757						
W530									
x85	55.7		0.951						
x74	49.5		0.845						
x66	43.8		0.748						

M/D RATIOS FOR CONTOUR PROTECTION
W SHAPES

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column
W360				
x1299		453		7.74
x1202		427		7.28
x1086		394		6.73
x990		366		6.24
x900		339		5.79
x818		313		5.34
x744		289		4.93
x677		267		4.56
x634		253		4.31
x592		238		4.07
x551		224		3.82
x509		209		3.56
x463		192		3.28
x421		177		3.02
x382		162		2.77
x347		148		2.53
x314		135		2.31
x287		125		2.14
x262		115		1.96
x237		104		1.78
x216		96.0		1.64
W360				
x196		90.6		1.55
x179		83.0		1.42
x162	91.2	75.4	1.56	1.29
x147	83.5	69.0	1.42	1.18
x134	76.2	63.0	1.30	1.07
W360				
x122	84.5	71.7	1.44	1.22
x110	76.8	65.1	1.31	1.11
x101	70.9	60.1	1.21	1.03
x91	64.0	54.3	1.09	0.927
W360				
x79	62.2	53.6	1.06	0.914
x72	56.5	48.7	0.965	0.831
x64	50.8	43.7	0.867	0.747
W360				
x57	47.5		0.810	
x51	42.7		0.728	
x45	38.1		0.651	
W360				
x39	37.1		0.633	
x33	31.3		0.535	

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column
W310				
x500		239		4.08
x454		220		3.76
x415		204		3.48
x375		187		3.20
x342		173		2.96
x313		160		2.73
x283		146		2.50
x253		132		2.26
x226		120		2.05
x202		108		1.85
x179		96.5		1.65
x158		85.9		1.47
x143		78.5		1.34
x129	86.2	71.5	1.47	1.22
x118	78.6	65.2	1.34	1.11
x107	71.8	59.6	1.23	1.02
x97	65.4	54.2	1.12	0.925
W310				
x86	64.7	54.4	1.10	0.928
x79	59.5	49.9	1.01	0.852
W310				
x74	62.3	53.1	1.06	0.907
x67	56.3	48.0	0.960	0.819
x60	50.5	43.0	0.861	0.734
W310				
x52	47.6		0.812	
x45	40.9		0.699	
x39	35.8		0.611	
W310				
x33	36.3		0.620	
x28	31.7		0.541	
x24	26.9		0.460	
x21	23.9		0.408	
W250				
x167		106		1.82
x149		95.8		1.64
x131		85.4		1.46
x115		75.5		1.29
x101	81.1	67.2	1.38	1.15
x89	72.3	59.9	1.23	1.02
x80	65.1	53.9	1.11	0.920
x73	59.6	49.3	1.02	0.842
W250				
x67	62.1	52.2	1.06	0.892
x58	54.4	45.8	0.929	0.781
x49	46.4	38.9	0.791	0.664
W250				
x45	47.7		0.814	
x39	41.4		0.707	
x33	35.4		0.605	

M/D RATIOS FOR CONTOUR PROTECTION

W SHAPES

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column
W250				
x28	35.7		0.610	
x25	32.0		0.547	
x22	28.5		0.486	
x18	22.9		0.391	
W200				
x100	95.9	79.8	1.64	1.36
x86	84.7	70.4	1.45	1.20
x71	70.9	58.9	1.21	1.00
x59	59.6	49.5	1.02	0.844
x52	53.0	43.9	0.904	0.749
x46	46.9	38.9	0.801	0.664
W200				
x42	47.7	40.1	0.814	0.684
x36	41.5	34.8	0.708	0.595
W200				
x31	39.5	33.8	0.675	0.577
x27	33.8	28.9	0.577	0.494
W200				
x22	32.5		0.555	
x19	28.4		0.485	
x15	22.1		0.378	
W150				
x37	49.1	40.8	0.839	0.697
x30	39.9	33.1	0.681	0.565
x22	30.4	25.2	0.519	0.430
W150				
x24	40.0	34.2	0.683	0.584
x18	30.6	26.0	0.522	0.445
x14	23.5	20.0	0.401	0.342
x13	22.0	18.8	0.376	0.320
W130				
x28		37.6		0.642
x24		32.1		0.547
W100				
x19		32.6		0.556

S SHAPES

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column
S610				
x180	104		1.78	
x158	91.4		1.56	
S610				
x149	89.9		1.54	
x134	81.4		1.39	
x119	72.3		1.23	
S510				
x143	97.8		1.67	
x128	88.3		1.51	
S510				
x112	79.8		1.36	
x98.2	70.6		1.21	
S460				
x104	81.4		1.39	
x81.4	63.8		1.09	
S380				
x74	67.7		1.16	
x64	58.2		0.993	
S310				
x74	79.9		1.36	
x60.7	65.6		1.12	
S310				
x52	56.8		0.969	
x47	51.7		0.882	
S250				
x52	65.1		1.11	
x38	47.6		0.813	
S200				
x34	52.3		0.892	
x27	41.9		0.715	
S150				
x26	50.0		0.853	
x19	36.5		0.624	
S130				
x15	34.1		0.581	
S100				
x14.1	38.5		0.657	
x11	31.4		0.536	
S75				
x11	37.8		0.645	
x8	28.9		0.494	

M/D RATIOS FOR CONTOUR PROTECTION
M SHAPES

Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.		Designation	SI (kg/m)/m		Imperial (lb./ft.)/in.	
	Beam	Column	Beam	Column		Beam	Column	Beam	Column
M318									
x18.5	20.3		0.347						
x17.3	19.5		0.332						
M310									
x17.6	21.4		0.365						
x16.1	19.7		0.336						
x14.9	17.9		0.306						
M250									
x13.4	19.4		0.330						
x11.9	17.3		0.296						
x11.2	16.2		0.276						
M200									
x9.7	17.2		0.294						
x9.2	16.4		0.280						
M150									
x6.6	15.1		0.259						
x5.5	12.6		0.214						
M130									
x28.1		38.5		0.657					
M100									
x8.9		15.9		0.271					
x6.1	18.0	15.5	0.308	0.265					
M75									
x4.3	15.2	12.8	0.259	0.218					

COEFFICIENTS OF THERMAL EXPANSION

(Linear, per degree × 10^{-6})

METALS	c per °C	c per °F
Aluminum	23	13
Brass	19	10.4
Bronze	18	10.1
Copper	16.7	9.3
Iron, Gray Cast	11	5.9
Iron, Wrought	12	6.7
Lead	28.7	15.9
Magnesium	28.8	16
Nickel	12.6	7
Steel, Cast	11.3	6.3
Steel, Stainless	17.8	9.9
Steel, Structural	11.7	6.5
Zinc, Rolled	31	17.3

NON-METALS	c per °C	c per °F
Cement, Portland	13	7
Concrete, Stone	10	5.7
Glass	7	4
Granite	8.3	4.6
Limestone	7.9	4.4
Marble	9	5
Masonry, Ashlar	6.3	3.5
Masonry, Brick	6.1	3.4
Masonry, Rubble	6.3	3.5
Plaster	16	9
Sandstone	11	6
Slate	10	5.8
Fir (parallel to fibre)	3.8	2.1
Fir (perpendicular to fibre)	58	32

NOTE: Coefficients of thermal expansion indicated are average values from various sources. Minor variations may be expected in metals. Large variations may be expected in concrete and masonry due to the many combinations of constituents possible.

Coefficients apply in general to a temperature range from 0 to 100 degrees Celsius.

The coefficient of linear thermal expansion (c) is the change in length per unit of length for a change of one degree of temperature. The coefficient for surface expansion is approximately two times, and the coefficient of volume expansion is approximately three times, the linear coefficient.

Change in length = $c\,L \times$ change in temperature, if member is free to elongate or contract.

Change in unit stress = $c\,E \times$ change in temperature, if member is not permitted to elongate or contract (E = modulus of elasticity).

CHECKLIST FOR DESIGN DRAWINGS

General

A design does not provide a satisfactory structure unless sufficient information is conveyed to the builder so that the designer's intentions are clearly understood. Furthermore, attempting to prepare an estimate for a structure from plans and specifications which contain insufficient information involves risks which tend to increase the tendered price. Clause 4.2 of CSA S16-14 governs the minimum requirements of design drawings. In addition, the following items are suggested as a checklist of information to be included on design drawings to avoid unnecessary and costly uncertainty at the time of bidding:

1. The type or types of design as defined in CSA S16-14. If plastic analysis is employed, it should be stated. Show the category of the structural system used for seismic design, as well as the seismic design criteria.
2. A list of design and material or product standards used. The grade(s) of structural steel, grade(s) and diameters of bolts.
3. All structural drawings to be adequately dimensioned, preferably in SI metric units. Do not intermix Metric and Imperial systems of units.
4. Centre-to-centre distances for all columns.
5. Outside dimensions of rigid frames and offset dimensions from grid lines to outside of rigid frames.
6. Out-to-out dimension of trusses and offset dimensions from centre line of chords to outside of chords–include any camber requirements.
7. Offset dimensions from centre of column lines to centre of beams for all beams that are not on the grid lines.
8. Relation of outside of exterior walls to centre lines of columns.
9. Relation of the top surfaces of beams to finished floor elevations.
10. Length of bearing for all beams bearing on exterior walls, including the dimension from the outside of the wall to the end of the steel beam and size of bearing plate.
11. Elevations of underside of column base plates.
12. Dimensions of all clear openings for doorways, ducts, stair wells, roof openings, etc., and their relation to adjacent steel members.
13. The specified dead, live, snow, rain, wind, seismic, and special loads, as well as design load criteria and/or parameters. Indicate whether loads and forces shown on drawings are factored or unfactored.
14. Axial loads in beams, columns and bracing members and joint pass-through forces. Forces and member sizes may be identified in beam or column schedules, or bracing elevation drawings.
15. Forces in truss members including moments when members are loaded between panel points.
16. Minimum end reactions required for all connections.
17. Moments for restrained beams and cantilevers. Governing combinations of shears, moments, and axial forces to be resisted by the connections.

18. All information necessary to design and manufacture the open-web steel joists and steel deck diaphragms to suit the loading conditions.
19. When a particular type of connection is required, the location and type of connection. Clear identification of structural connections that are critical for ductile seismic response. Locations and dimensions of protected zones.
20. Type of beam-to-column connection when beams frame over top of columns, including type and location of stiffeners.
21. Any bearing-type connections that are required to be pretensioned. The designation of joints as bearing or slip-critical.
22. For composite beams, the size and location of shear studs and which beams, if any, must be shored.
23. Size of column base plates and size and location of anchor rods or shear lugs. (Column bases require a minimum of four anchor rods unless special precautions are taken.)
24. Size and location of stiffeners, web doubler plates, reinforcement, and bracing required for stability of compression elements.
25. Details and location of built-up lintels.
26. Identify roof cladding systems that do not provide lateral restraint to the roof structure.
27. Reinforcement, where necessary, for openings through beam webs or openings in the steel deck diaphragm for rooftop units.
28. Ledger angles complete with method of attachment.
29. Members requiring prime paint or galvanizing.
30. Identify architecturally exposed structural steel elements requiring special tolerances and finishes. (Also refer to the CISC Code of Standard Practice in Part 7.)
31. Treatment of steel encased in concrete.
32. Fabrication and erection tolerances if other than those specified in CSA S16-14. Special tolerances when interfacing with other materials, i.e., steel attached to concrete.
33. A note that all structural welding is to be performed only by companies certified to Division 1 or 2.1 of CSA W47.1.
34. When weld symbols are shown, refer to "WELDED JOINTS Standard Symbols" in Part 6.

Allow as much time as possible (three weeks for an average job) for preparing bids. During the time allotted for preparing tenders, only those changes necessary to clarify bidding instructions should be issued by addendum. If major changes are included in an addendum, an extension of the tender closing should be considered.

PROPERTIES OF GEOMETRIC SECTIONS
Definitions

Neutral Axis

The line, in any given section of a member subject to bending, on which there is neither tension nor compression.

For pure elastic bending of a straight beam, the neutral axis at any cross-section is coincident with the centroidal axis of the cross-section.

In the case of fully plastic bending, the neutral axis divides the sectional area equally. Therefore, the neutral axis for elastic and plastic bending coincide only in the case of sections symmetrical about the neutral axis.

Moment of Inertia I

The sum of the products obtained by multiplying each of the elementary areas, of which the section is composed, by the square of its perpendicular distance from the axis about which the moment of inertia is being calculated.

Elastic Section Modulus S

The moment of inertia divided by the perpendicular distance from the axis about which the moment of inertia has been calculated to the most remote part of the section.

The elastic section modulus is used to determine the bending stress in the extreme fibre of a section by dividing the bending moment by the section modulus, referred to the neutral axis perpendicular to the plane of bending, both values being expressed in like units of measure.

Radius of Gyration r

The perpendicular distance from a neutral axis to the centre of gyration (i.e., the point where the entire area is considered to be concentrated so as to have the same moment of inertia as the actual area). The square of the radius of gyration of a section is equal to the moment of inertia (referred to the appropriate axis) divided by the area.

The radius of gyration of a section is used to ascertain the load this section will sustain when used in compression as a strut or column. The ratio of the effective unsupported length of the section divided by the least radius of gyration applicable to this length is called the slenderness ratio.

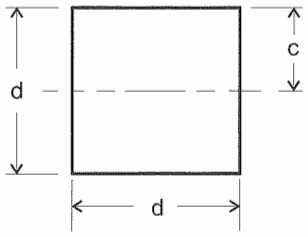
Plastic Modulus Z

The modulus of resistance to bending of a completely yielded cross-section, calculated by taking the combined statical moment, about the neutral axis, of the cross-sectional areas above and below that axis.

In general, the plastic modulus is calculated by simple statics and has been included for only a few of the shapes listed.

SQUARE

Axis of moments through centre



$$A = d^2$$

$$c = \frac{d}{2}$$

$$I = \frac{d^4}{12}$$

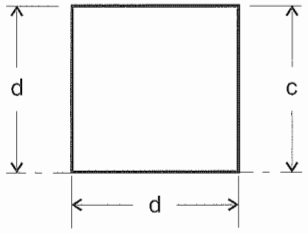
$$S = \frac{d^3}{6}$$

$$r = \frac{d}{\sqrt{12}}$$

$$Z = \frac{d^3}{4}$$

SQUARE

Axis of moments on base



$$A = d^2$$

$$c = d$$

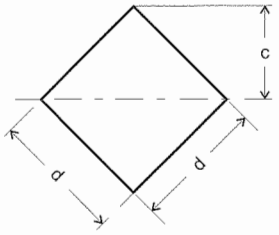
$$I = \frac{d^4}{3}$$

$$S = \frac{d^3}{3}$$

$$r = \frac{d}{\sqrt{3}}$$

SQUARE

Axis of moments on diagonal



$$A = d^2$$

$$c = \frac{d}{\sqrt{2}}$$

$$I = \frac{d^4}{12}$$

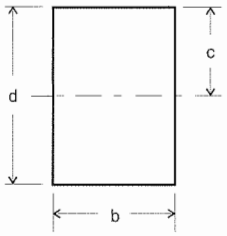
$$S = \frac{d^3}{6\sqrt{2}}$$

$$r = \frac{d}{\sqrt{12}}$$

$$Z = \frac{2c^3}{3} = \frac{d^3}{3\sqrt{2}}$$

RECTANGLE

Axis of moments through centre



$$A = bd$$

$$c = \frac{d}{2}$$

$$I = \frac{bd^3}{12}$$

$$S = \frac{bd^2}{6}$$

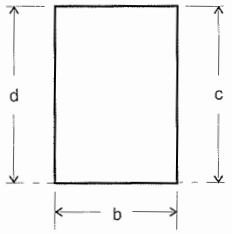
$$r = \frac{d}{\sqrt{12}}$$

$$Z = \frac{bd^2}{4}$$

PROPERTIES OF GEOMETRIC SECTIONS

RECTANGLE

Axis of moments on base



$$A = bd$$

$$c = d$$

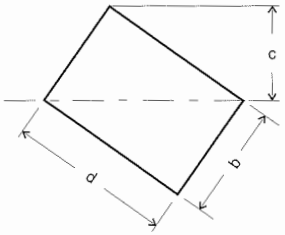
$$I = \frac{bd^3}{3}$$

$$S = \frac{bd^2}{3}$$

$$r = \frac{d}{\sqrt{3}}$$

RECTANGLE

Axis of moments on diagonal



$$A = bd$$

$$c = \frac{bd}{\sqrt{b^2 + d^2}}$$

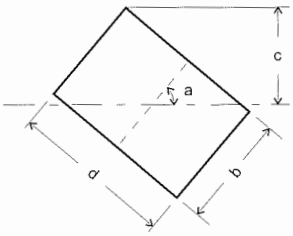
$$I = \frac{b^3d^3}{6\left(b^2 + d^2\right)}$$

$$S = \frac{b^2d^2}{6\sqrt{b^2 + d^2}}$$

$$r = \frac{bd}{\sqrt{6\left(b^2 + d^2\right)}}$$

RECTANGLE

Axis of moments any line through centre of gravity



$$A = bd$$

$$c = \frac{b \sin a + d \cos a}{2}$$

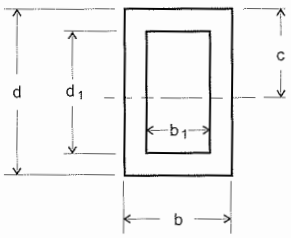
$$I = \frac{bd\left(b^2 \sin^2 a + d^2 \cos^2 a\right)}{12}$$

$$S = \frac{bd\left(b^2 \sin^2 a + d^2 \cos^2 a\right)}{6\left(b \sin a + d \cos a\right)}$$

$$r = \sqrt{\frac{b^2 \sin^2 a + d^2 \cos^2 a}{12}}$$

HOLLOW RECTANGLE

Axis of moments through centre



$$A = bd - b_1d_1$$

$$c = \frac{d}{2}$$

$$I = \frac{bd^3 - b_1d_1^3}{12}$$

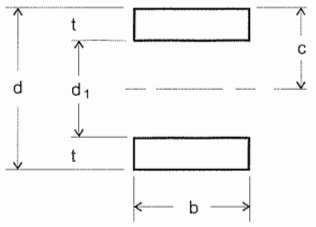
$$S = \frac{bd^3 - b_1d_1^3}{6d}$$

$$r = \sqrt{\frac{bd^3 - b_1d_1^3}{12A}}$$

$$Z = \frac{1}{4}\left(bd^2 - b_1d_1^2\right)$$

EQUAL RECTANGLES

Axis of moments through centre of gravity



$$A = b(d - d_1)$$

$$c = \frac{d}{2}$$

$$I = \frac{b(d^3 - d_1^3)}{12}$$

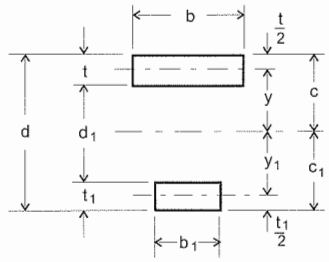
$$S = \frac{b(d^3 - d_1^3)}{6d}$$

$$r = \sqrt{\frac{d^3 - d_1^3}{12(d - d_1)}}$$

$$Z = \frac{b}{4}(d^2 - d_1^2) = bt(d - t)$$

UNEQUAL RECTANGLES

Axis of moments through centre of gravity



$$A = bt + b_1t_1$$

$$c = \frac{½bt^2 + b_1t_1(d - ½t_1)}{A}$$

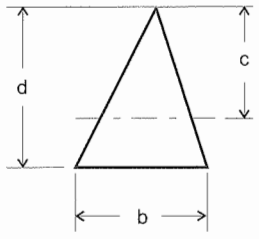
$$I = \frac{bt^3}{12} + bty^2 + \frac{b_1t_1^3}{12} + b_1t_1y_1^2$$

$$S = \frac{I}{c} \qquad S_1 = \frac{I}{c_1}$$

$$r = \sqrt{\frac{I}{A}}$$

TRIANGLE

Axis of moments through centre of gravity



$$A = \frac{bd}{2}$$

$$c = \frac{2d}{3}$$

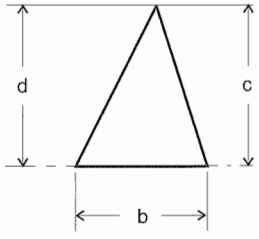
$$I = \frac{bd^3}{36}$$

$$S = \frac{bd^2}{24}$$

$$r = \frac{d}{\sqrt{18}}$$

TRIANGLE

Axis of moments on base



$$A = \frac{bd}{2}$$

$$c = d$$

$$I = \frac{bd^3}{12}$$

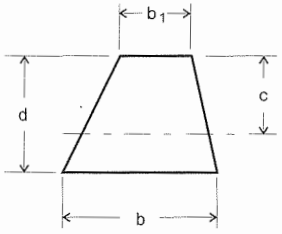
$$S = \frac{bd^2}{12}$$

$$r = \frac{d}{\sqrt{6}}$$

PROPERTIES OF GEOMETRIC SECTIONS

TRAPEZOID

Axis of moments through centre of gravity



$$A = \frac{d(b + b_1)}{2}$$

$$c = \frac{d(2b + b_1)}{3(b + b_1)}$$

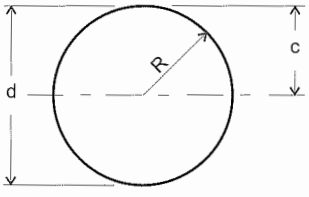
$$I = \frac{d^3(b^2 + 4bb_1 + b_1^2)}{36(b + b_1)}$$

$$S = \frac{d^2(b^2 + 4bb_1 + b_1^2)}{12(2b + b_1)}$$

$$r = \frac{d}{6(b + b_1)}\sqrt{2(b^2 + 4bb_1 + b_1^2)}$$

CIRCLE

Axis of moments through centre



$$A = \frac{\pi d^2}{4} = \pi R^2$$

$$c = \frac{d}{2} = R$$

$$I = \frac{\pi d^4}{64} = \frac{\pi R^4}{4}$$

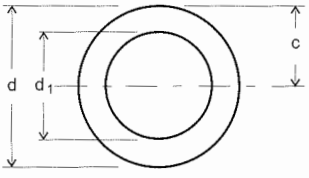
$$S = \frac{\pi d^3}{32} = \frac{\pi R^3}{4}$$

$$r = \frac{d}{4} = \frac{R}{2}$$

$$Z = \frac{d^3}{6}$$

HOLLOW CIRCLE

Axis of moments through centre



$$A = \frac{\pi(d^2 - d_1^2)}{4}$$

$$c = \frac{d}{2}$$

$$I = \frac{\pi(d^4 - d_1^4)}{64}$$

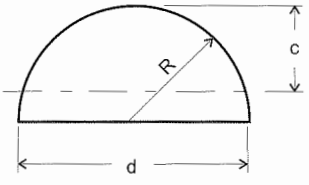
$$S = \frac{\pi(d^4 - d_1^4)}{32d}$$

$$r = \frac{\sqrt{d^2 + d_1^2}}{4}$$

$$Z = \frac{1}{6}(d^3 - d_1^3)$$

HALF CIRCLE

Axis of moments through centre of gravity



$$A = \frac{\pi R^2}{2}$$

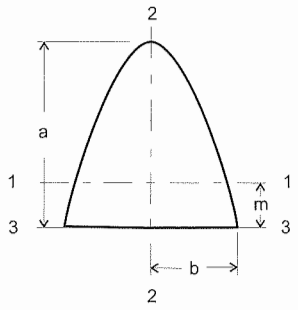
$$c = R\left(1 - \frac{4}{3\pi}\right)$$

$$I = R^4\left(\frac{\pi}{8} - \frac{8}{9\pi}\right)$$

$$S = \frac{R^3}{24}\frac{(9\pi^2 - 64)}{(3\pi - 4)}$$

$$r = R\frac{\sqrt{9\pi^2 - 64}}{6\pi}$$

PARABOLA



$$A = \frac{4}{3}ab$$

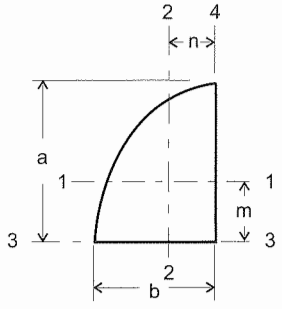
$$m = \frac{2}{5}a$$

$$I_1 = \frac{16}{175}a^3L$$

$$I_2 = \frac{4}{15}ab^3$$

$$I_3 = \frac{32}{105}a^3b$$

HALF PARABOLA



$$A = \frac{2}{3}ab$$

$$m = \frac{2}{5}a$$

$$n = \frac{3}{8}b$$

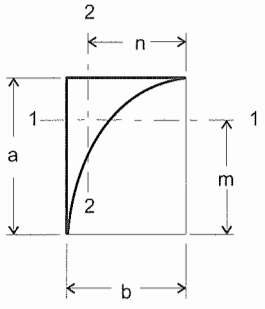
$$I_1 = \frac{8}{175}a^3b$$

$$I_2 = \frac{19}{480}ab^3$$

$$I_3 = \frac{16}{105}a^3b$$

$$I_4 = \frac{2}{15}ab^3$$

COMPLEMENT OF HALF PARABOLA



$$A = \frac{1}{3}ab$$

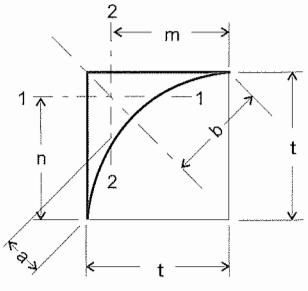
$$m = \frac{7}{10}a$$

$$n = \frac{3}{4}b$$

$$I_1 = \frac{37}{2100}a^3b$$

$$I_2 = \frac{1}{80}ab^3$$

PARABOLIC FILLET IN RIGHT ANGLE



$$a = \frac{t}{2\sqrt{2}}$$

$$b = \frac{t}{\sqrt{2}}$$

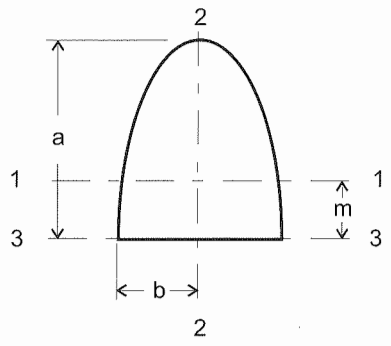
$$A = \frac{1}{6}t^2$$

$$m = n = \frac{4}{5}t$$

$$I_1 = I_2 = \frac{11}{2100}t^4$$

PROPERTIES OF GEOMETRIC SECTIONS

* HALF ELLIPSE



$$A = \frac{1}{2}\pi ab$$

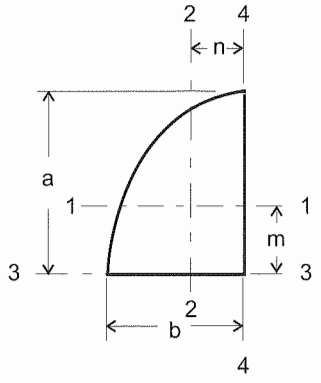
$$m = \frac{4a}{3\pi}$$

$$I_1 = a^3b\left(\frac{\pi}{8} - \frac{8}{9\pi}\right)$$

$$I_2 = \frac{1}{8}\pi ab^3$$

$$I_3 = \frac{1}{8}\pi a^3b$$

* QUARTER ELLIPSE



$$A = \frac{1}{4}\pi ab$$

$$m = \frac{4a}{3\pi}$$

$$n = \frac{4b}{3\pi}$$

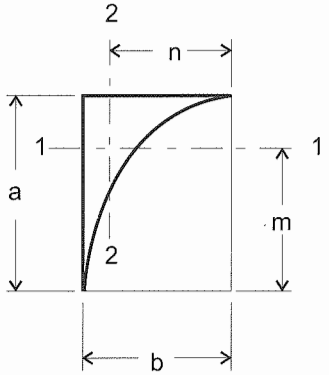
$$I_1 = a^3b\left(\frac{\pi}{16} - \frac{4}{9\pi}\right)$$

$$I_2 = ab^3\left(\frac{\pi}{16} - \frac{4}{9\pi}\right)$$

$$I_3 = \frac{1}{16}\pi a^3b$$

$$I_4 = \frac{1}{16}\pi ab^3$$

* ELLIPTIC COMPLEMENT

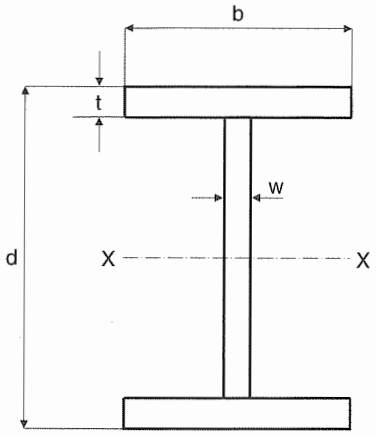


$$A = ab\left(1 - \frac{\pi}{4}\right), \quad m = \frac{a}{6\left(1 - \frac{\pi}{4}\right)}, \quad n = \frac{b}{6\left(1 - \frac{\pi}{4}\right)}$$

$$I_1 = a^3b\left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{36\left(1 - \frac{\pi}{4}\right)}\right)$$

$$I_2 = ab^3\left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{36\left(1 - \frac{\pi}{4}\right)}\right)$$

* To obtain properties of half circle, quarter circle and circle complement substitute $a = b = R$.



$$A = 2bt + (d - 2t)w$$

$$I = \frac{1}{12}\left[bd^3 - (b - w)(d - 2t)^3\right]$$

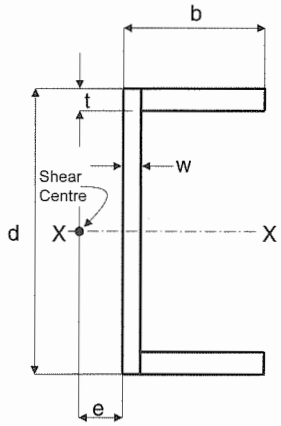
$$S = \frac{1}{6d}\left[bd^3 - (b - w)(d - 2t)^3\right]$$

$$r = \sqrt{\frac{I}{A}}$$

$$Z = \frac{1}{4}\left[bd^2 - (b - w)(d - 2t)^2\right]$$

$$J = \frac{1}{3}\left[2bt^3 + (d - t)w^3\right]$$

$$C_w = \frac{1}{24}(d - t)^2 b^3 t$$



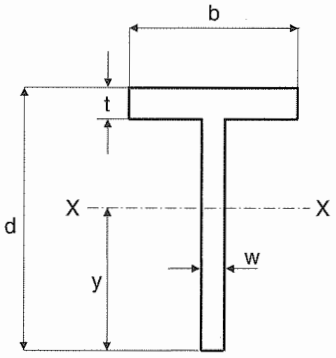
$$A = dw + 2(b - w)t$$

$$I = \frac{1}{12}\left[bd^3 - (b - w)(d - 2t)^3\right]$$

$$S = \frac{1}{6d}\left[bd^3 - (b - w)(d - 2t)^3\right]$$

$$r = \sqrt{\frac{I}{A}}$$

$$e = \frac{3t(b - w/2)^2}{6t(b - w/2) + (d - t)w} - \frac{w}{2}$$



$$A = bt + w(d - t)$$

$$y = \frac{1}{2}\left(\frac{bdt}{A} + d - t\right)$$

$$I = \frac{1}{12}\left[bt^3 + w(d - t)^3 + \frac{3bwtd^2(d - t)}{A}\right]$$

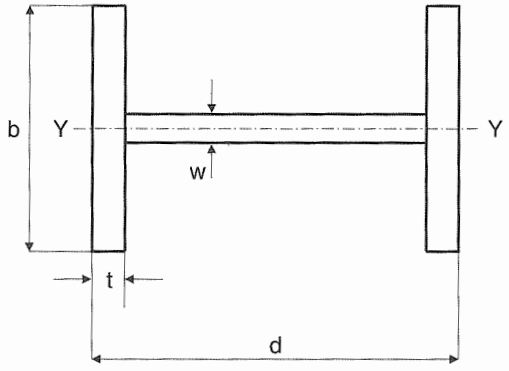
$$S_1 = \frac{I}{y};\quad S_2 = \frac{I}{d - y}$$

$$r = \sqrt{\frac{I}{A}}$$

$$J = \frac{1}{3}\left[bt^3 + (d - \frac{t}{2})w^3\right]$$

$$C_w = \frac{b^3 t^3}{144} + \frac{(d - \frac{t}{2})^3 w^3}{36}$$

PROPERTIES OF GEOMETRIC SECTIONS AND STRUCTURAL SHAPES



$$A = 2bt + w(d - 2t)$$

$$I = \frac{1}{12}\left[2tb^3 + (d - 2t)w^3\right]$$

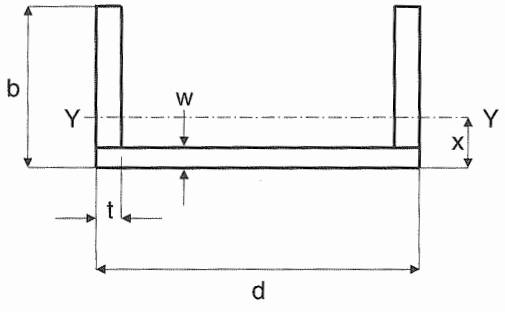
$$S = \frac{1}{6b}\left[2tb^3 + (d - 2t)w^3\right]$$

$$r = \sqrt{\frac{I}{A}}$$

$$Z = \frac{1}{4}\left[2t(b^2 - w^2) + dw^2\right]$$

$$J = \frac{1}{3}\left[2bt^3 + (d - t)w^3\right]$$

$$C_w = \frac{1}{24}(d - t)^2 b^3 t$$



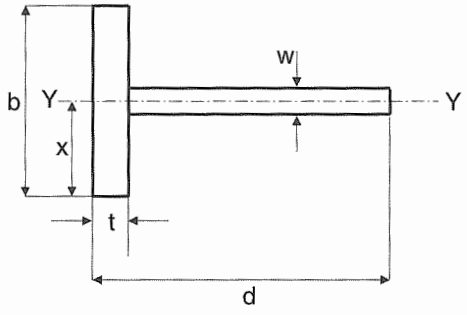
$$A = dw + 2(b - w)t$$

$$x = \frac{1}{2A}\left[(d - 2t)w^2 + 2tb^2\right]$$

$$I = \frac{1}{3}\left[dx^3 + 2t(b - x)^3 - (d - 2t)(x - w)^3\right]$$

$$S_1 = \frac{I}{b - x}; \qquad S_2 = \frac{I}{x}$$

$$r = \sqrt{\frac{I}{A}}$$



$$A = bt + (d - t)w$$

$$x = b/2$$

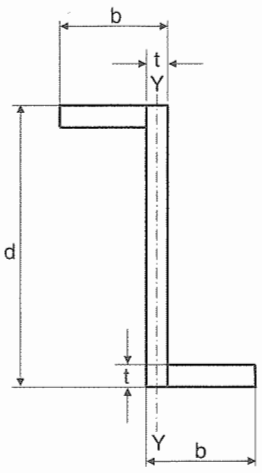
$$I = \frac{1}{12}\left[tb^3 + (d - t)w^3\right]$$

$$S = \frac{2I}{b}$$

$$r = \sqrt{\frac{I}{A}}$$

$$J = \frac{1}{3}\left[bt^3 + (d - \frac{t}{2})w^3\right]$$

$$C_w = \frac{b^3 t^3}{144} + \frac{(d - \frac{t}{2})^3 w^3}{36}$$



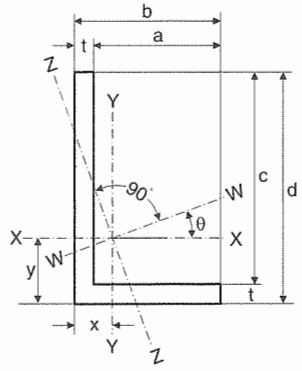
$$J = \frac{1}{3}\left[2b + d - 2t\right]t^3$$

$$C_w = \frac{(d-t)^2(b-t/2)^3 t}{12}\left[\frac{b+2d-5t/2}{d+2b-2t}\right]$$

See next page for other section properties.

ANGLE

Axis of moments through
Centre of gravity



Z-Z is axis of minimum I

$$\tan 2\theta = \frac{2K}{I_y - I_x}$$

$$A = t(b + c) \qquad x = \frac{b^2 + ct}{2(b + c)} \qquad y = \frac{d^2 + at}{2(b + c)}$$

K = Product of Inertia about X-X & Y-Y

$$= \mp \frac{abcdt}{4(b + c)}$$

$$I_x = \frac{1}{3}\left[t(d - y)^3 + by^3 - a(y - t)^3\right]$$

$$I_y = \frac{1}{3}\left[t(b - x)^3 + dx^3 - c(x - t)^3\right]$$

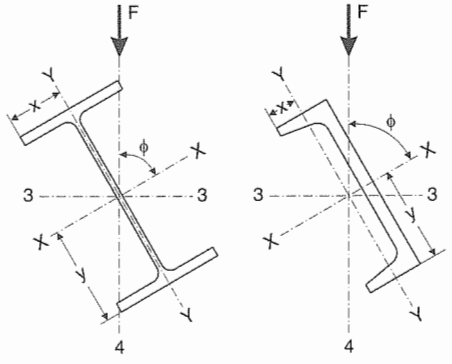
$$I_z = I_x \sin^2\theta + I_y \cos^2\theta + K\sin 2\theta$$

$$I_w = I_x \cos^2\theta + I_y \sin^2\theta - K\sin 2\theta$$

K is negative when heel of angle, with respect to c.g., is in 1st or 3rd quadrant, positive when in 2nd or 4th quadrant.

BEAMS AND CHANNELS

Transverse force oblique
through centre of gravity



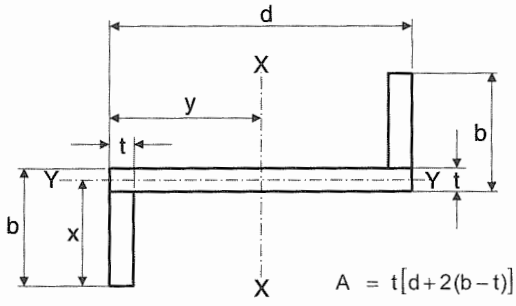
$$I_3 = I_x \sin^2\phi + I_y \cos^2\phi$$

$$I_4 = I_x \cos^2\phi + I_y \sin^2\phi$$

$$f = M\left(\frac{y}{I_x}\sin\phi + \frac{x}{I_y}\cos\phi\right)$$

where M is bending moment due to force F.

PROPERTIES OF GEOMETRIC SECTIONS AND STRUCTURAL SHAPES



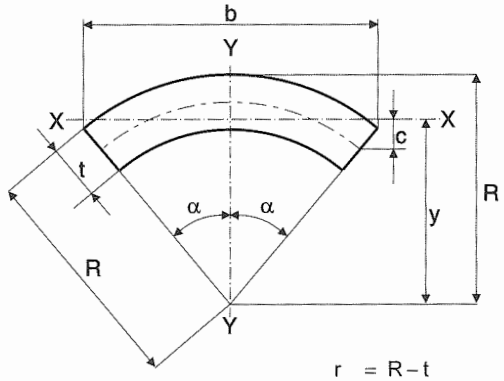
$$A = t[d+2(b-t)]$$

$$x = b-\frac{t}{2}$$

$$I_x = \frac{1}{12}\left[d^3 b-(d-2t)^3(b-t)\right] \qquad I_y = \frac{1}{12}\left[(2b-t)^3 t+(d-t)t^3\right]$$

$$S_x = \frac{I_x}{y} \qquad S_y = \frac{I_y}{x}$$

$$r_x = \sqrt{\frac{I_x}{A}} \qquad r_y = \sqrt{\frac{I_y}{A}}$$



$$r = R-t$$

$$A = \frac{\pi\alpha}{180}(R^2-r^2)$$

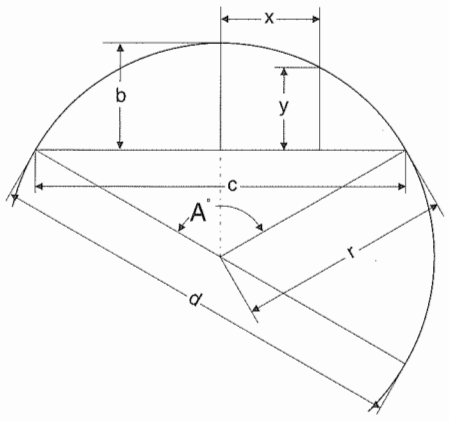
$$b = 2R\sin\alpha$$

$$c = \frac{120\sin\alpha\,(R^3-r^3)}{\pi\alpha(R^2-r^2)} - \frac{(R+r)\cos\alpha}{2}$$

$$y = \frac{120\sin\alpha\,(R^3-r^3)}{\pi\alpha(R^2-r^2)}$$

$$I_x = \frac{1}{4}(R^4-r^4)\left(\frac{\pi\alpha}{180}+\sin\alpha\cos\alpha\right) - \frac{80\sin^2\alpha(R^3-r^3)^2}{\pi\alpha(R^2-r^2)}$$

$$I_y = \frac{1}{4}(R^4-r^4)\left(\frac{\pi\alpha}{180}-\sin\alpha\cos\alpha\right)$$



Circumference = $6.28318r = 3.14159d$
Diameter = 0.31831 circumference
Area = $3.14159r^2$

Arc a = $\dfrac{\pi r A^\circ}{180^\circ} = 0.017453 r A^\circ$

Angle A° = $\dfrac{180^\circ a}{\pi r} = 57.29578\dfrac{a}{r}$

Radius r = $\dfrac{4b^2 + c^2}{8b}$

Chord c = $2\sqrt{2br - b^2} = 2r\sin\dfrac{A}{2}$

Rise b = $r - \dfrac{1}{2}\sqrt{4r^2 - c^2} = \dfrac{c}{2}\tan\dfrac{A}{4}$

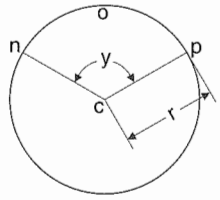
$= 2r\sin^2\dfrac{A}{4} = r + y - \sqrt{r^2 - x^2}$

y = $b - r + \sqrt{r^2 - x^2}$

x = $\sqrt{r^2 - (r + y - b)^2}$

Diameter of circle of equal periphery as square	= 1.27324 side of square
Side of square of equal periphery as circle	= 0.78540 diameter of circle
Diameter of circle circumscribed about square	= 1.41421 side of square
Side of square inscribed in circle	= 0.70711 diameter of circle

CIRCULAR SECTOR



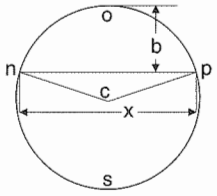
r = radius of circle, y = angle ncp in degrees

Area of Sector ncpo = $\frac{1}{2}$(length of arc nop × r)

= Area of Circle × $\dfrac{y}{360}$

= $0.0087266 \times r^2 \times y$

CIRCULAR SEGMENT



r = radius of circle, x = chord, b = rise

Area of Segment nop = Area of Sector ncpo − Area of triangle ncp

= $\dfrac{(\text{Length of arc nop} \times r) - x(r - b)}{2}$

Area of Segment nsp = Area of Circle − Area of Segment nop

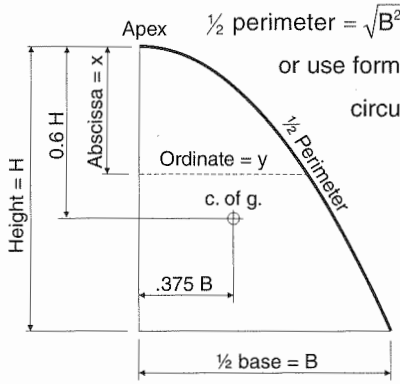
PROPERTIES OF PARABOLA AND ELLIPSE

PARABOLA

When $H \div B = 0.1$ or less, approximate

½ perimeter $= \sqrt{B^2 + 4/3H^2}$

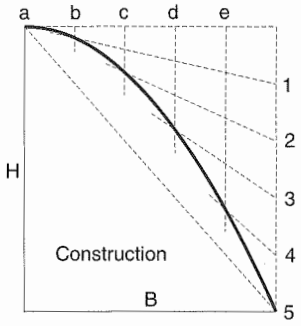
or use formulas for circular arcs



Parameter $P = B^2 \div H$ Area = ⅔ HB

$x = y^2 \div P$

$y = \sqrt{xP}$

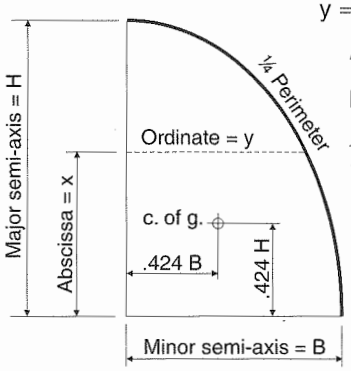


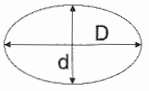
ELLIPSE

$(x^2 \div H^2) + (y^2 \div B^2) = 1$ $x = (H \div B)\sqrt{B^2 - y^2}$

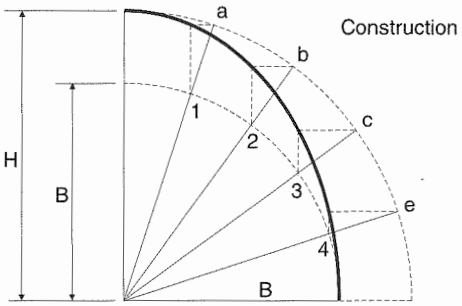
$y = (B \div H)\sqrt{H^2 - x^2}$

Approximate ¼ perimeter = $\frac{\pi}{4}\sqrt{2(H^2 + B^2)}$

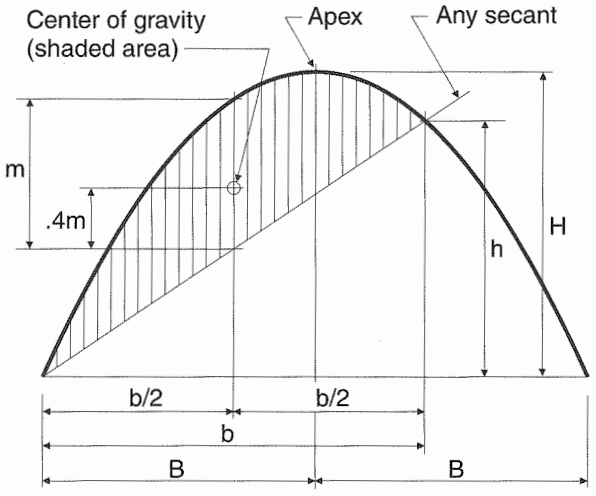




Area = .7854 Dd



AREA BETWEEN PARABOLIC CURVE AND SECANT



Length b may vary from 0 to 2B

$$h = Hb\left(\frac{2B - b}{B^2}\right)$$

$$m = \frac{Hb^2}{4B^2}$$

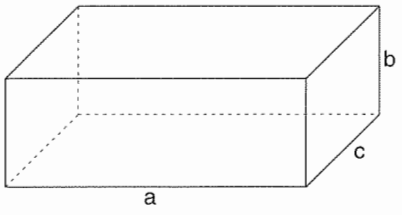
Shaded area = ⅔ bm

$$= \frac{Hb^3}{6B^2}$$

RECTANGULAR PARALLELEPIPED

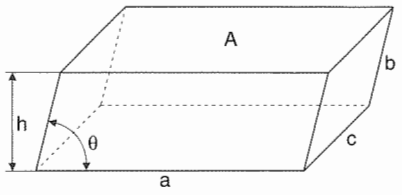
Volume = abc

Surface area = $2(ab + ac + bc)$



PARALLELEPIPED

Volume = Ah = abc $\sin\theta$

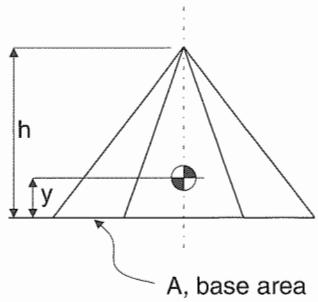


PYRAMID

Volume = $\frac{1}{3}$Ah

The centroid of a pyramid is located y-distance from the base on the line joining the centre of gravity of area A and the apex.

$y = \frac{h}{4}$

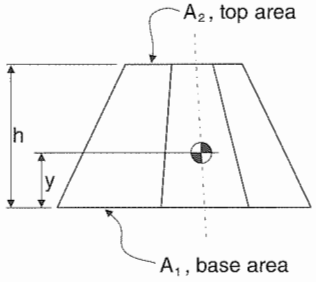


FRUSTUM OF PYRAMID

$V = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$

The centroid is located y-distance up from area A_1 on the line joining the centres of gravity of areas A_1 and A_2.

$y = \frac{h\left(A_1 + 2\sqrt{A_1 A_2} + 3A_2\right)}{4\left(A_1 + \sqrt{A_1 A_2} + A_2\right)}$

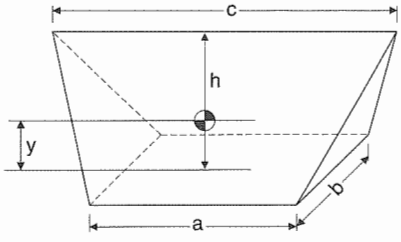


WEDGE

$V = \frac{(2a + c)\,bh}{6}$

The centroid is located y-distance from the base on the line joining the centre of gravity of the base area and the mid point of edge, c.

$y = \frac{h(a + c)}{2(2a + c)}$



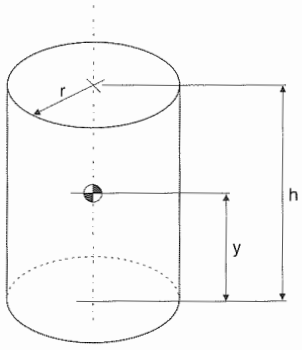
PROPERTIES OF SOLIDS

RIGHT CIRCULAR CYLINDER

Volume $= \pi r^2 h$

Lateral surface area $= 2\pi rh$

$y = \frac{h}{2}$

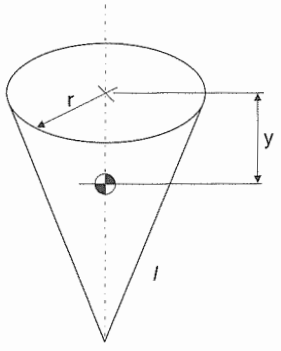


RIGHT CIRCULAR CONE

Volume $= \frac{1}{3}\pi r^2 h$

Lateral surface area $= \pi r\sqrt{r^2 + h^2} = \pi rl$

$y = \frac{h}{4}$



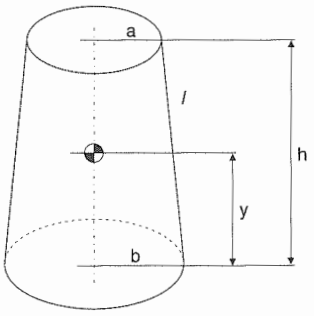
FRUSTUM OF RIGHT CIRCULAR CONE

Volume $= \frac{1}{3}\pi h\left(a^2 + ab + b^2\right)$

Lateral surface area $= \pi(a+b)\sqrt{h^2 + (b-a)^2}$

$= \pi(a+b)l$

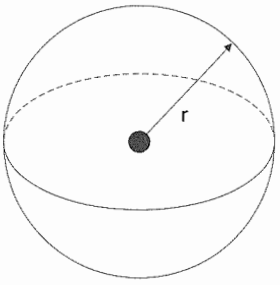
$y = \frac{h\left(b^2 + 2ab + 3a^2\right)}{4\left(b^2 + ab + a^2\right)}$



SPHERE

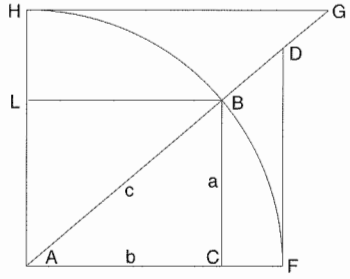
Volume $= \frac{4}{3}\pi r^3$

Surface area $= 4\pi r^2$



TRIGONOMETRIC FORMULAE

TRIGONOMETRIC FUNCTIONS



Radius AF $= 1$

$= \sin^2 A + \cos^2 A = \sin A \operatorname{cosec} A$

$= \cos A \sec A = \tan A \cot A$

Sine A $= \dfrac{\cos A}{\cot A} = \dfrac{1}{\operatorname{cosec} A} = \cos A \tan A = \sqrt{1-\cos^2 A}$ $= BC$

Cosine A $= \dfrac{\sin A}{\tan A} = \dfrac{1}{\sec A} = \sin A \cot A = \sqrt{1-\sin^2 A}$ $= AC$

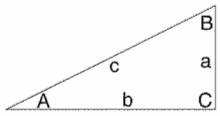
Tangent A $= \dfrac{\sin A}{\cos A} = \dfrac{1}{\cot A} = \sin A \sec A$ $= FD$

Cotangent A $= \dfrac{\cos A}{\sin A} = \dfrac{1}{\tan A} = \cos A \operatorname{cosec} A$ $= HG$

Secant A $= \dfrac{\tan A}{\sin A} = \dfrac{1}{\cos A}$ $= AD$

Cosecant A $= \dfrac{\cot A}{\cos A} = \dfrac{1}{\sin A}$ $= AG$

RIGHT ANGLED TRIANGLES



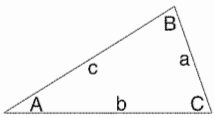
$a^2 = c^2 - b^2$

$b^2 = c^2 - a^2$

$c^2 = a^2 + b^2$

Known	Required					
	A	B	a	b	c	Area
a, b	$\tan A = \dfrac{a}{b}$	$\tan B = \dfrac{b}{a}$			$\sqrt{a^2+b^2}$	$\dfrac{ab}{2}$
a, c	$\sin A = \dfrac{a}{c}$	$\cos B = \dfrac{a}{c}$		$\sqrt{c^2-a^2}$		$\dfrac{a\sqrt{c^2-a^2}}{2}$
A, a		$90° - A$		$a \cot A$	$\dfrac{a}{\sin A}$	$\dfrac{a^2 \cot A}{2}$
A, b		$90° - A$	$b \tan A$		$\dfrac{b}{\cos A}$	$\dfrac{b^2 \tan A}{2}$
A, c		$90° - A$	$c \sin A$	$c \cos A$		$\dfrac{c^2 \sin 2A}{4}$

OBLIQUE ANGLED TRIANGLES



$$s = \frac{a+b+c}{2}$$

$$K = \sqrt{\frac{(s-a)(s-b)(s-c)}{s}}$$

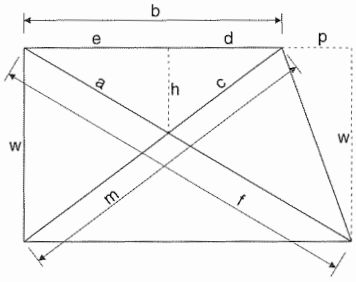
$a^2 = b^2 + c^2 - 2bc\cos A$

$b^2 = a^2 + c^2 - 2ac\cos B$

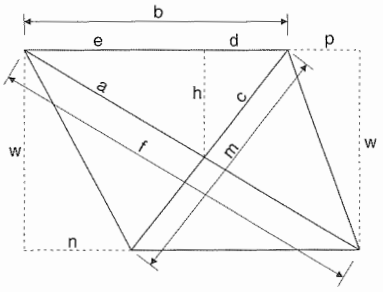
$c^2 = a^2 + b^2 - 2ab\cos C$

Known	Required					
	A	B	C	b	c	Area
a, b, c	$\tan\frac{1}{2}A = \dfrac{K}{s-a}$	$\tan\frac{1}{2}B = \dfrac{K}{s-b}$	$\tan\frac{1}{2}C = \dfrac{K}{s-c}$			$\sqrt{s(s-a)(s-b)(s-c)}$
a, A, B			$180° - (A+B)$	$\dfrac{a \sin B}{\sin A}$	$\dfrac{a \sin C}{\sin A}$	
a, b, A		$\sin B = \dfrac{b \sin A}{a}$			$\dfrac{b \sin C}{\sin B}$	
a, b, C	$\tan A = \dfrac{a \sin C}{b - a\cos C}$				$\sqrt{a^2+b^2-2ab\cos C}$	$\dfrac{ab \sin C}{2}$

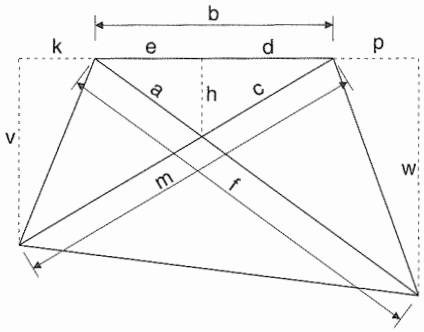
BRACING FORMULAE



Given	To Find	Formula
bpw	f	$\sqrt{(b+p)^2+w^2}$
bw	m	$\sqrt{b^2+w^2}$
bp	d	$b^2 \div (2b+p)$
bp	e	$b(b+p) \div (2b+p)$
bfp	a	$bf \div (2b+p)$
bmp	c	$bm \div (2b+p)$
bpw	h	$bw \div (2b+p)$
afw	h	$aw \div f$
cmw	h	$cw \div m$

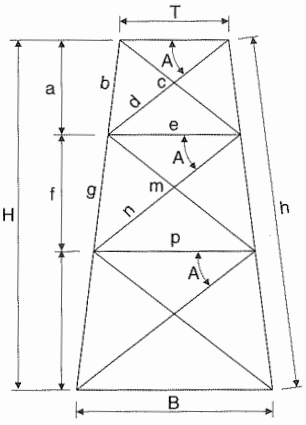


Given	To Find	Formula
bpw	f	$\sqrt{(b+p)^2+w^2}$
bnw	m	$\sqrt{(b-n)^2+w^2}$
bnp	d	$b(b-n) \div (2b+p-n)$
bnp	e	$b(b+p) \div (2b+p-n)$
bfnp	a	$bf \div (2b+p-n)$
bmnp	c	$bm \div (2b+p-n)$
bnpw	h	$bw \div (2b+p-n)$
afw	h	$aw \div f$
cmw	h	$cw \div m$



Given	To Find	Formula
bpw	f	$\sqrt{(b+p)^2+w^2}$
bkv	m	$\sqrt{(b+k)^2+v^2}$
bkpvw	d	$bw(b+k) \div [v(b+p)+w(b+k)]$
bkpvw	e	$bv(b+p) \div [v(b+p)+w(b+k)]$
bfkpvw	a	$fbv \div [v(b+p)+w(b+k)]$
bkmpvw	c	$bmw \div [v(b+p)+w(b+k)]$
bkpvw	h	$bvw \div [v(b+p)+w(b+k)]$
afw	h	$aw \div f$
cmv	h	$cv \div m$

PARALLEL BRACING



$k = (\log B - \log T) \div$ no. of panels. Constant k plus the logarithm of any line equals the log of the corresponding line in the next panel below.

$a = TH \div (T+e+p)$

$b = Th \div (T+e+p)$

$c = \sqrt{(\frac{1}{2}T + \frac{1}{2}e)^2 + a^2}$

$d = ce \div (T+e)$

$\log e = k + \log T$

$\log f = k + \log a$

$\log g = k + \log b$

$\log m = k + \log c$

$\log n = k + \log d$

$\log p = k + \log e$

The above method can be used for any number of panels.
In the formulas for "a" and "b" the sum in parenthesis, which in the case shown is $(T+e+p)$, is always composed of all the horizontal distances except the base.

LENGTH OF CIRCULAR ARCS FOR UNIT RADIUS

By the use of this table, the length of any arc may be found if the length of the radius and the angle of the segment are known.

Example: Required the length of arc of segment 32° 15' 27" with radius of 8 000 mm.

From table: Length of arc (Radius 1) for

32°	=	.5585054
15'	=	.0043633
27"	=	.0001309
		.5629996

.5629996 X 8 000 (length of radius) = 4504 mm

For the same arc but with the radius expressed as 24 feet 3 inches, the length of arc would be 0.5629996 X 24.25 = 13.65 feet

DEGREES						MINUTES		SECONDS	
1	.017 4533	61	1.064 6508	121	2.111 8484	1	.000 2909	1	.000 0048
2	.034 9066	62	1.082 1041	122	2.129 3017	2	.000 5818	2	.000 0097
3	.052 3599	63	1.099 5574	123	2.146 7550	3	.000 8727	3	.000 0145
4	.069 8132	64	1.117 0107	124	2.164 2083	4	.001 1636	4	.000 0194
5	.087 2665	65	1.134 4640	125	2.181 6616	5	.001 4544	5	.000 0242
6	.104 7198	66	1.151 9173	126	2.199 1149	6	.001 7453	6	.000 0291
7	.122 1730	67	1.169 3706	127	2.216 5682	7	.002 0362	7	.000 0339
8	.139 6263	68	1.186 8239	128	2.234 0214	8	.002 3271	8	.000 0388
9	.157 0796	69	1.204 2772	129	2.251 4747	9	.002 6180	9	.000 0436
10	.174 5329	70	1.221 7305	130	2.268 9280	10	.002 9089	10	.000 0485
11	.191 9862	71	1.239 1838	131	2.286 3813	11	.003 1998	11	.000 0533
12	.209 4395	72	1.256 6371	132	2.303 8346	12	.003 4907	12	.000 0582
13	.226 8928	73	1.274 0904	133	2.321 2879	13	.003 7815	13	.000 0630
14	.244 3461	74	1.291 5436	134	2.338 7412	14	.004 0724	14	.000 0679
15	.261 7994	75	1.308 9969	135	2.356 1945	15	.004 3633	15	.000 0727
16	.279 2527	76	1.326 4502	136	2.373 6478	16	.004 6542	16	.000 0776
17	.296 7060	77	1.343 9035	137	2.391 1011	17	.004 9451	17	.000 0824
18	.314 1593	78	1.361 3568	138	2.408 5544	18	.005 2360	18	.000 0873
19	.331 6126	79	1.378 8101	139	2.426 0077	19	.005 5269	19	.000 0921
20	.349 0659	80	1.396 2634	140	2.443 4610	20	.005 8178	20	.000 0970
21	.366 5191	81	1.413 7167	141	2.460 9142	21	.006 1087	21	.000 1018
22	.383 9724	82	1.431 1700	142	2.478 3675	22	.006 3995	22	.000 1067
23	.401 4257	83	1.448 6233	143	2.495 8208	23	.006 6904	23	.000 1115
24	.418 8790	84	1.466 0766	144	2.513 2741	24	.006 9813	24	.000 1164
25	.436 3323	85	1.483 5299	145	2.530 7274	25	.007 2722	25	.000 1212
26	.453 7856	86	1.500 9832	146	2.548 1807	26	.007 5631	26	.000 1261
27	.471 2389	87	1.518 4364	147	2.565 6340	27	.007 8540	27	.000 1309
28	.488 6922	88	1.535 8897	148	2.583 0873	28	.008 1449	28	.000 1357
29	.506 1455	89	1.553 3430	149	2.600 5406	29	.008 4358	29	.000 1406
30	.523 5988	90	1.570 7963	150	2.617 9939	30	.008 7266	30	.000 1454
31	.541 0521	91	1.588 2496	151	2.635 4472	31	.009 0175	31	.000 1503
32	.558 5054	92	1.605 7029	152	2.652 9005	32	.009 3084	32	.000 1551
33	.575 9587	93	1.623 1562	153	2.670 3538	33	.009 5993	33	.000 1600
34	.593 4119	94	1.640 6095	154	2.687 8070	34	.009 8902	34	.000 1648
35	.610 8652	95	1.658 0628	155	2.705 2603	35	.010 1811	35	.000 1697
36	.628 3185	96	1.675 5161	156	2.722 7136	36	.010 4720	36	.000 1745
37	.645 7718	97	1.692 9694	157	2.740 1669	37	.010 7629	37	.000 1794
38	.663 2251	98	1.710 4227	158	2.757 6202	38	.011 0538	38	.000 1842
39	.680 6784	99	1.727 8760	159	2.775 0735	39	.011 3446	39	.000 1891
40	.698 1317	100	1.745 3293	160	2.792 5268	40	.011 6355	40	.000 1939
41	.715 5850	101	1.762 7825	161	2.809 9801	41	.011 9264	41	.000 1988
42	.733 0383	102	1.780 2358	162	2.827 4334	42	.012 2173	42	.000 2036
43	.750 4916	103	1.797 6891	163	2.844 8867	43	.012 5082	43	.000 2085
44	.767 9449	104	1.815 1424	164	2.862 3400	44	.012 7991	44	.000 2133
45	.785 3982	105	1.832 5957	165	2.879 7933	45	.013 0900	45	.000 2182
46	.802 8515	106	1.850 0490	166	2.897 2466	46	.013 3809	46	.000 2230
47	.820 3047	107	1.867 5023	167	2.914 6999	47	.013 6717	47	.000 2279
48	.837 7580	108	1.884 9556	168	2.932 1531	48	.013 9626	48	.000 2327
49	.855 2113	109	1.902 4089	169	2.949 6064	49	.014 2535	49	.000 2376
50	.872 6646	110	1.919 8622	170	2.967 0597	50	.014 5444	50	.000 2424
51	.890 1179	111	1.937 3155	171	2.984 5130	51	.014 8353	51	.000 2473
52	.907 5712	112	1.954 7688	172	3.001 9663	52	.015 1262	52	.000 2521
53	.925 0245	113	1.972 2221	173	3.019 4196	53	.015 4171	53	.000 2570
54	.942 4778	114	1.989 6753	174	3.036 8729	54	.015 7080	54	.000 2618
55	.959 9311	115	2.007 1286	175	3.054 3262	55	.015 9989	55	.000 2666
56	.977 3844	116	2.024 5819	176	3.071 7795	56	.016 2897	56	.000 2715
57	.994 8377	117	2.042 0352	177	3.089 2328	57	.016 5806	57	.000 2763
58	1.012 2910	118	2.059 4885	178	3.106 6861	58	.016 8715	58	.000 2812
59	1.029 7443	119	2.076 9418	179	3.124 1394	59	.017 1624	59	.000 2860
60	1.047 1976	120	2.094 3951	180	3.141 5927	60	.017 4533	60	.000 2909

SI SUMMARY

General

The following information on SI units is provided to assist those involved in the planning, design, fabrication and erection of steel structures prepared in SI units. Information related to the metric system in general is to be found in CAN3-Z234.1-79, "Canadian Metric Practice Guide" and for terms related to the steel industry in the "Industry Practice Guide for SI Metric Units in the Canadian Iron and Steel Industry". The latter is available from the Task Force for Metric Conversion in the Canadian Iron and Steel Industry, P.O. Box 4248, Station "D", Hamilton, Ontario, L8V 4L6.

The eleventh General Conference of Weights and Measures, in 1960, adopted the name International System of Units for a coherent system which includes the metre as the base unit of length and the kilogram as the base unit of mass. The international abbreviation of the name of this system, in all languages, is SI.

Canada is a signatory to the General Conference on Weights and Measures, and in 1970, the Canadian government stated that the eventual conversion to the metric system is an objective of Canadian policy. Since that time, metric conversion activity in Canada has developed to the point where material and design standards, building codes and technical literature are available in SI units.

The SI system is based on the seven base units listed in Table 7-1. Decimal multiples and sub-multiples of the SI base units are formed by the addition of the prefixes given in Table 7-2.

SI BASE UNITS
Table 7-1

Quantity	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

SI PREFIXES
Table 7-2

Multiplying Factor	Prefix	Symbol
$1\,000\,000\,000\,000 = 10^{12}$	tera	T
$1\,000\,000\,000 = 10^{9}$	giga	G
$1\,000\,000 = 10^{6}$	mega	M
$1\,000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10^{1}$	deca	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000\,001 = 10^{-6}$	micro	μ
$0.000\,000\,001 = 10^{-9}$	nano	n
$0.000\,000\,000\,001 = 10^{-12}$	pico	p
$0.000\,000\,000\,000\,001 = 10^{-15}$	femto	f
$0.000\,000\,000\,000\,000\,001 = 10^{-18}$	atto	a

In choosing the appropriate decimal multiple or sub-multiple, the Canadian Metric Practice Guide recommends the use of prefixes representing 10 raised to a power that is a multiple of 3, a ternary power. Thus, common structural steel design units would be:

Force - newton (N), kilonewton (kN)
Stress - pascal (Pa), kilopascal (kPa), megapascal (MPa)
Length - millimetre (mm), metre (m)
Mass - kilogram (kg), megagram (Mg)

The tonne is a special unit, equal to 1 000 kg (or 1 Mg) that will be used in the basic steel industry, but should not be used in structural design calculations.

Designers using SI units must transform loads given in mass (kilograms) to forces, using the relationship force = mass times acceleration. In the design of structures on earth, acceleration is the acceleration due to gravity, designated by "g" and established as 9.806 65 metres per second per second at the third General Conference on Weights and Measures in 1901.

The unit of force to be used in design is the newton (N) (or multiples thereof) where a newton is defined as the force that, when applied to a body having a mass of one kilogram (kg), gives the body an acceleration of one metre (m) per second squared (s^2). The unit of stress is the pascal (Pa), which is one newton per square metre (m^2). Since this is a very small unit, designers of steel structures will generally use megapascals (MPa), where one megapascal is one million pascals and equals one newton per square millimetre (N/mm^2). See also "Structural Loads, Mass and Force".

Properties and dimensions of steel sections are given, in this book, in millimetre units, tabulated to an appropriate ternary power of 10, and millimetres should be used for dimensioning steel structures. Some relationships and values of interest to steel designers are shown below:

SI PREFIXES
Table 7-3

Density of Steel		7 850	kg/m^3
Modulus of Elasticity	E	200 000	MPa
Shear Modulus of Steel	G	77 000	MPa
Coefficient of Thermal Expansion		11.7×10^{-6}	/°C
Acceleration due to Earth's Gravity	g	9.806 65	m/s^2

For a more complete description of SI, the Canadian Metric Practice Guide should be consulted; however, Table 7-4 provides a convenient summary listing selected SI units, the quantity represented, the unit name and typical application.

Structural Loads, Mass and Force

Since most civil engineers have been accustomed to designing structures on earth to withstand loads more variable than the acceleration due to gravity, the pound-force and the kilogram-force have been used as standard units of force. These units were assumed to be numerically equal to their mass counter-parts, the pound-mass and the kilogram-mass respectively.

In SI, the units of mass and force, the kilogram and the newton respectively, are distinctly different both in name and in value. The two are related through the famous Newtonian equation, force = mass times acceleration, or

$$F = ma$$

Thus a newton (N) is defined as the force required to give one kilogram (kg) mass an acceleration of one metre (m) per second (s) squared, or

$$1\ N = 1\ kg{\cdot}m/s^2$$

The standard international value of acceleration due to gravity is $9.806\ 65\ m/s^2$. However, for hand calculations in Canada a value of

$$g = 9.81\ m/s^2$$

may be more acceptable as it retains three significant figures (adequate for most structural design) and produces a numerical value of force distinctly different from the value of mass. Thus, whether or not the mass has been converted to a force will be readily apparent, and errors will tend to be reduced.

SELECTED SI UNITS
Table 7-4

Quantity	Preferred Units	Unit Name	Typical Applications	Remarks
Area	mm^2	square millimetre	Area of cross section for structural sections	Avoid cm^2
	m^2	square metre	Areas in general	
Bending Moment	kN·m	kilonewton metre	Bending moment in structural sections	
Coating mass	g/m^2	gram per square metre	Mass of zinc coating on steel deck	
Coefficient of Thermal Expansion	$1/°C$ *	reciprocal (of) degree Celsius	Expansion of materials subject to temperature change (generally expressed as a ratio per degree Celsius)	$11.7 \times 10^{-6}/°C$ for steel
Density, mass	kg/m^3	kilogram per cubic metre	Density of materials in general; mass per unit volume	7 850 kg/m^3 for steel
Force	N	newton	Unit of force used in structural calculations	$1N = 1 kg \cdot m/s^2$
	kN	kilonewton	Force in structural elements such as columns; concentrated forces; axial forces; reactions; shear force; gravitational force	
Force per Unit Length	N/m	newton per metre	Unit for use in calculations	$1 kg/m \times 9.81 m/s^2 = (9.81 kg \cdot m/s^2) \times \frac{1}{m} = 9.81 N/m$
	kN/m	kilonewton per metre	Transverse force per unit length on a beam, column etc.; dead load of a beam for stress calculations	$(1 kg/m \times 9.81 m/s^2) \times \frac{1\,000}{1\,000} = (9.81 kg \cdot m/s^2) \times \frac{1}{m} \times \frac{1\,000}{1\,000} = (9.81 N/m) \times \frac{1\,000}{1\,000} = 9.81 kN/m \times 1/1\,000 = 0.009\,81 kN/m$
Force per Unit Area (See Pressure)				
Frequency	Hz	hertz	Frequency of vibration	1 Hz = 1/s = s^{-1} replaces cycle per second (cps)
Impact energy	J	joule	Charpy V-notch test	1 N·m = 1 J
Length	mm	millimetre	Dimensions on all drawings; dimensions of sections, spans, deflection, elongations, eccentricity	
	m	metre	Overall dimensions; in calculations; contours; surveys	
	km	kilometre	Distances for transportation purposes	
	µm	micrometre	Thickness of coatings (paint)	
Mass	kg	kilogram	Mass of materials, structural elements and machinery	A metric tonne, t $1t = 10^3 kg = 1Mg = 1\,000 kg$
Mass per Unit Length	kg/m	kilogram per metre	Mass per unit length of section, bar, or similar items of uniform cross section.	Also known as "linear density"
Mass per Unit Area	kg/m^2	kilogram per square metre	Mass per unit area of plates, slabs, or similar items of uniform thickness; rating for load-carrying capacities on floors (display on notices only)	DO NOT USE IN STRESS CALCULATION
Mass Density	kg/m^3	kilogram per cubic metre	Density of materials in general; mass per unit volume	7 850 kg/m^3 for steel
Modulus of Elasticity (Young's)	MPa	megapascal	Modulus of elasticity; Young's modulus	200 000 MPa for carbon, high-strength low alloy and low-alloy wrought steels
Modulus, Shear	MPa	megapascal	Shear Modulus	77 000 MPa assumed for steel
Modulus, Section	mm^3	millimetre to third power	First moment of area of cross section of structural section, such as plastic section modulus, elastic section modulus	

* The preferred unit is 1/K, however $1/°C$ is an acceptable unit for the construction industry

SELECTED SI UNITS
Table 7-4

Quantity	Preferred Units	Unit Name	Typical Applications	Remarks
Moment of Inertia	mm^4	millimetre to fourth power	Second moment of area; moment of inertia of a section; torsional constant of cross section	
Moment of Force	kN·m	kilonewton metre	Bending moment (in structural sections); overturning moment	
	N·m	newton metre		
Pressure (see also Stress)	Pa	pascal	Unit used in calculation	1 Pa = 1 N/m^2
	kPa	kilopascal	Uniformly distributed loads on floors; soil pressure, wind loads; snow loads; dead loads; live loads.	1 kPa = 1 kN/m^2
Section Modulus (see Modulus)				
Stress	MPa	megapascal	Stress (yield, ultimate, permitted, calculated) in structural steel	1 MPa = 1 MN/m^2 = 1 N/mm^2
Structural Load (see Force)				
Temperature	°C	degree Celsius	Ambient temperature	0°C ≈ 273.15K However, for temperature intervals 1°C = 1K
Thickness	mm	millimetre	Thickness of web, flange, plate, etc.	
	μm	micrometre	Thickness of paint	
Torque	kN·m	kilonewton metre	Torsional moment on a cross section	
Volume	m^3	cubic metre	Volume; volume of earthworks, excavation, concrete, sand, all bulk materials.	1 m^3 = 1 000 L The cubic metre is the preferred unit of volume for engineering purposes
	L	litre	Volume of fluids and containers for fluids	
Work, Energy	J	joule	Energy absorbed in impact testing of materials; energy in general	1 kWh = 3.6 MJ where kWh is a kilowatt hour.

There are two common areas where the designer of a structure must be alert to the distinction between mass and force:

1. dead loads due to the mass of the structural elements, permanent equipment etc.,
2. superimposed, or live loads due to storage of materials.

In these and other cases where mass is well known since it is the unit of commerce, the designer must convert mass to force by multiplying by g.

COMMON CONVERSION FACTORS
Table 7-5

Item	Imperial – SI	SI – Imperial
Acceleration	1 ft./s^2 = 0.304 8 m/s^2	1 m/s^2 = 3.2808 ft./s^2
Area	1 acre = 0.404 685 6 ha 1 ft.^{2} = 0.092 903 04 m^2 1 in.^{2} = 645.16 mm^2 1 mi.^{2} = 2.589 988 km^2 1 yd.^{2} = 0.836 127 4 m^2	1 ha = 2.471 acres 1 m^2 = 10.764 ft.^{2} 1 mm^2 = 1.55 x 10^{-3} in.^{2} 1 km^2 = 0.3861 mi.^{2} 1 m^2 = 1.20 yd.^{2}
Capacity (Canadian Legal Units)	1 oz. = 28.413 062 mL 1 gal. = 4.546 090 L 1 pt. = 0.568 261 L 1 qt. = 1.136 522 L	1 mL = 35.2 x 10^{-3} oz. 1 L = 0.220 gal. 1 L = 1.76 pt. 1 L = 0.880 qt.
Density, Mass	1 lb./ft. = 1.488 16 kg/m 1 lb./yd. = 0.496 055 kg/m 1 oz./ft.^{2} = 305.152 g/m^2 1 lb./ft.^{2} = 4.882 43 kg/m^2 1 lb./in.^{2} = 703.069 6 kg/m^2 1 lb./ft.^{3} = 16.018 46 kg/m^3 1 lb./in.^{3} = 27.679 90 Mg/m^3	1 kg/m = 0.672 lb./ft. 1 kg/m = 2.016 lb./yd. 1 g/m^2 = 3.277 x 10^{-3} oz./ft.^{2} 1 kg/m^2 = 0.205 lb./ft.^{2} 1 kg/m^2 = 1.42 x 10^{-3} lb./in.^{2} 1 kg/m^3 = 62.4 x 10^{-3} lb./ft.^{3} 1 Mg/m^3 = 0.0361 lb./in.^{3}
Force	1 kip = 4.448 222 kN	1 kN = 0.225 kip
Length	1 ft. = 0.304 8 m = 304.8 mm 1 in. = 25.4 mm 1 mile = 1.609 344 km 1 yd. = 0.914 4 m	1 m = 3.28 ft. 1 mm = 0.0394 in. 1 km = 0.622 mi. 1 m = 1.09 yd.
Mass	1 lb. = 0.453 592 37 kg 1 ton (2000 lb.) = 0.907 184 74 Mg	1 kg = 2.205 lb. 1 Mg = 1.10 ton = 2205 lb.
Mass per Unit Area	1 lb./ft.^{2} = 4.882 43 kg/m^2	1 kg/m^2 = 0.205 lb./ft.^{2}
Mass per Unit Length	1 lb./ft. = 1.488 16 kg/m	1 kg/m = 0.672 lb./ft.
Moment of Inertia a) Second Moment of Area b) Section Modulus	1 in.^{4} = 416 231.4 mm^4 1 in.^{3} = 16 387.064 mm^3	1 mm^4 = 2.4 x 10^{-6} in.^{4} 1 mm^3 = 0.061 x 10^{-3} in.^{3}
Pressure or Stress	1 ksi = 6.894 757 MPa 1 psf = 47.880 26 Pa 1 psi = 6.894 757 kPa	1 MPa = 0.145 ksi 1 Pa = 0.0209 psf 1 kPa = 0.145 psi
Torque or Moment of Force	1 ft.·kipf = 1.355 818 kN·m	1 kN·m = 0.738 ft.·kipf
Volume	1 in.^{3} = 16 387.064 mm^3 1 ft.^{3} = 28.316 85 dm^3 1 yd.^{3} = 0.764 555 m^3	1 mm^3 = 0.061 x 10^{-3} in.^{3} 1 dm^3 = 0.0353 ft.^{3} 1 m^3 = 1.308 yd.^{3}
Costs	1 $/ft. = 3.28 $/m 1 $/ft.^{2} = 10.764 $/m^2 1 $/yd.^{2} = 1.20 $/m^2 1 $/ft.^{3} = 35.34 $/m^3 1 $/yd.^{3} = 1.307 $/m^3	1 $/m = 0.305 $/ft. 1 $/m^2 = 0.0929 $/ft.^{2} 1 $/m^2 = 0.836 $/yd.^{2} 1 $/m^3 = 0.0283 $/ft.^{3} 1 $/m^3 = 0.765 $/yd.^{3}

MILLIMETRE EQUIVALENTS
DECIMALS AND EACH 64TH OF AN INCH

FRACTIONS	INCHES	mm
1/64	.015625	.397
1/32	.03125	.794
	.03937	①
3/64	.046875	1.191
1/16	.0625	1.588
5/64	.078125	1.984
	.07874	②
3/32	.09375	2.381
7/64	.109375	2.778
	.11811	③
1/8	.125	3.175
9/64	.140625	3.572
5/32	.15625	3.969
	.15748	④
11/64	.171875	4.366
3/16	.1875	4.763
	.19685	⑤
13/64	.203125	5.159
7/32	.21875	5.556
15/64	.234375	5.953
	.23622	**6**
¼	.25	6.350
17/64	.265625	6.747
	.27559	**7**
9/32	.28125	7.144
19/64	.296875	7.541
5/16	.3125	7.938
	.31496	**8**
21/64	.328125	8.334
11/32	.34375	8.731
	.35433	**9**
23/64	.359375	9.128
3/8	.375	9.525
25/64	.390625	9.922
	.3937	⑩
13/32	.40625	10.319
27/64	.421875	10.716
	.43307	**11**
7/16	.4375	11.113
29/64	.453125	11.509
15/32	.46875	11.906
	.47244	**12**
31/64	.484375	12.303
½	.5	12.700

FRACTIONS	INCHES	mm
	.51181	**13**
33/64	.515625	13.097
17/32	.53125	13.494
35/64	.546875	13.891
	.55118	**14**
9/16	.5625	14.288
37/64	.578125	14.684
	.59055	⑮
19/32	.59375	15.081
39/64	.609375	15.478
5/8	.625	15.875
	.62992	**16**
41/64	.640625	16.272
21/32	.65625	16.669
	.66929	**17**
43/64	.671875	17.066
11/16	.6875	17.463
45/64	.703125	17.859
	.70866	**18**
23/32	.71875	18.256
47/64	.734375	18.653
	.74893	**19**
¾	.75	19.050
49/64	.765625	19.447
25/32	.781250	19.844
	.7874	⑳
51/64	.796875	20.241
13/16	.8125	20.638
	.82677	**21**
53/64	.828125	21.034
27/32	.84375	21.431
55/64	.859375	21.828
	.86614	**22**
7/8	.875	22.225
57/64	.890625	22.622
	.90551	**23**
29/32	.90625	23.019
59/64	.921875	23.416
15/16	.9375	23.813
	.94488	**24**
61/64	.953125	24.209
31/32	.96875	24.606
	.98425	㉕
63/64	.984375	25.003
①	1.000	25.4

MISCELLANEOUS CONVERSION FACTORS

Area

1 acre	= 0.404 685 6 ha
1 hectare	= **1** hm^2
1 legal subdivision (40 acres)	= 0.161 874 2 km^2
1 section (1 mile square, 640 acres)	= 2.589 988 km^2
1 square foot	= **929.0304** cm^2
1 square inch	= **645.16** mm^2
1 square mile	= 2.589 988 km^2
1 square yard	= 0.836 127 4 m^2
1 township (36 sections)	= 93.239 57 km^2

Linear Density (Mass per Unit Length)

1 pound per inch	= 17.858 kg/m
1 pound per foot	= 1.488 16 kg/m
1 pound per yard	= 0.496 055 kg/m

Area Density (Mass per Unit Area)

1 ounce per square foot	= 305.152 g/m^2
1 pound per square foot	= 4.882 43 kg/m^2
1 pound per square inch	= 703.0696 kg/m^2

Mass Density (Mass per Unit Volume)

1 pound per cubic foot	= 16.018 46 kg/m^3
1 pound per cubic inch	= 27.679 90 Mg/m^3
1 ton (long) per cubic yard	= 1.328 939 Mg/m^3
1 ton (short) per cubic yard	= 1.186 553 Mg/m^3

Energy

1 British thermal unit (Btu) (International Table)	= **1.055 056** kJ
1 foot pound-force	= 1.355 818 J
1 horsepower hour	= 2.684 52 MJ
1 kilowatt hour	= **3.6** MJ

Force

1 kilogram-force	= **9.806 65** N
1 kip (thousand pounds force)	= 4.448 222 kN
1 pound-force	= 4.448 222 N

Heat

1 Btu *foot per (square foot hour °F)	= 1.730 74 W/(m·K)	k-value
1 Btu per (square foot hour °F)	= 5.678 29 $W/(m^2 \cdot K)$	U-value
1 square foot hour °F per Btu	= 0.176 109 $m^2 \cdot K/W$	R-value

** Based on the Btu IT.*

Length

1 chain (66 feet)	= **20.1168** m
1 foot	= **0.3048** m
1 inch	= **25.4** mm
1 microinch	= **25.4** nm
1 micron	= **1** μm
1 mil (0.001 inch)	= **25.4** μm
1 mile	= **1.609 344** km
1 mile (International nautical)	= **1.852** km
1 mile (UK nautical)	= **1.853 184** km
1 mile (US nautical)	= **1.852** km
1 yard	= **0.9144** m

MISCELLANEOUS CONVERSION FACTORS

Mass

1 hundredweight (100 lb)	= **45.359 237** kg
1 hundredweight (long) (112 lb, UK)	= 50.802 345 kg
1 pennyweight	= 1.555 174 g
1 pound (avoirdupois)	= **0.453 592 37** kg
1 ton (long, 2240 lb, UK)	= **1.016 046 908 8** Mg
1 ton (short, 2000 lb)	= **0.907 184 74** Mg

Mass Concentration

1 pound per cubic foot	= 16.018 46 kg/m^3

Second Moment of Area (Moment of Inertia)

1 inch^4	= 0.416 231 4 $\times 10^6$ mm^4

Section Modulus

1 inch^3	= **16.387 064** $\times$ **10^3** mm^3

Momentum

1 pound foot per second	= 0.138 255 kg·m/s

Power. See also Energy.

1 Btu (IT)* per hour	= 0.293 072 W
1 foot pound-force per hour	= 0.376 616 1 mW
1 foot pound-force per minute	= 22.596 97 mW
1 foot pound-force per second	= 1.355 818 W
1 horsepower (550 ft·lbf/s)	= 745.6999 W

* *International Tables.*

Pressure or Stress (Force per Area)

1 atmosphere, standard	= **101.325** kPa
1 inch of mercury (conventional, 32°F)	= 3.386 39 kPa
1 inch of water (conventional)	= 249.089 Pa
1 ksi (1000 lbf/in^2)	= 6.894 757 MPa
1 mm mercury (conventional, 0°C)	= 133.322 Pa
1 pound-force per square foot	= 47.880 26 Pa
1 pound-force per square inch (psi)	= 6.894 757 kPa
1 ton-force per square inch	= 13.789 514 MPa
1 ton-force (UK) per square inch	= 15.4443 MPa

Temperature

Scales

Celsius * temperature	= temperature in kelvins – **273.15**
Fahrenheit temperature	= **1.8** (Celsius temperature) + **32**
Fahrenheit temperature	= **1.8** (temperature in kelvins) – **459.67**
Rankine temperature	= **1.8** (temperature in kelvins)

Intervals

1 degree Celsius*	= **1** K
1 degree Fahrenheit	= **5/9** K
1 degree Rankine	= **5/9** K

* "Celsius" replaced "Centigrade" in 1948 to eliminate confusion with the word centigrade, associated with centesimal angular measure.

MISCELLANEOUS CONVERSION FACTORS

Time

1 day (mean solar)	= **86.4** ks
1 hour (mean solar)	= **3.6** ks
1 minute (mean solar)	= **60** s
1 month (mean calendar, 365/12 days)	= **2.628** Ms
1 year (calendar, 365 days)	= **31.536** Ms

Torque (Moment of Force)

1 pound-force foot	= 1.355 818 N·m
1 pound-force inch	= 0.112 985 N·m

Volume

1 acre foot	= 1233.482 m^3
1 barrel (oil, 42 US gallons)	= **0.158 987 3** m^3
1 board foot*	= 2.359 737 dm^3
1 cubic foot	= 28.316 85 dm^3
1 cubic inch	= **16.387 064** cm^3
1 cubic yard	= 0.764 555 m^3
1 gallon	= **4.546 09** dm^3
1 gallon (UK) §	= 4.546 092 dm^3
1 gallon (US)	= 3.785 412 dm^3

** The board foot is nominally $1 \times 12 \times 12 = 144$ in^3. However, the actual volume of wood is about 2/3 of the nominal quantity.*

§ Also referred to as the "Imperial gallon."

Volume Rate of Flow

1 cubic foot per minute	= 0.471 947 4 dm^3/s
1 cubic foot per second	= 28.316 85 dm^3/s
1 cubic yard per minute	= 12.742 58 dm^3/s
1 gallon per minute	= 75.768 17 cm^3/s
1 gallon (UK) per minute	= 75.7682 cm^3/s
1 gallon (US) per minute	= 63.0902 cm^3/s
1 million gallons per day	= 52.6168 dm^3/s

Notes:

1. The conversion factors give the relationship between SI units and other Canadian legal units as well as commonly encountered units of measure of United Kingdom and USA origin. The yard and the pound are the same throughout the world; by definition they are specified fractions of the metre and the kilogram. The gallons of Canada and Australia, which are identical, differ by a relatively insignificant amount from the gallon of the United Kingdom, whereas that of the USA is a much smaller measure.
2. The conversion factors given in tables apply to Canadian units unless stated otherwise.
3. Conversion factors that are exact are shown in boldface type. Other factors are given to more than sufficient accuracy for most general and scientific work.
4. Conversions are those listed in CAN3-Z234.1-79