

CoTM 6203 Advanced Construction Material & Equipment Management

Lecture 3- Cold-formed Steel

Introduction

- The use of iron dates back to about 1500 B.C, when primitive furnaces were used to heat the **ore in a charcoal fire**.
- Ferrous metals were produced on a relatively small scale until the blast furnace was developed in the 18th century.
- Steel production started in mid-1800s, when the ***Bessemer converter*** was invented.

Advancement in steel production

- In the 2nd half of the 19th century, steel technology advanced rapidly due to the development of the *Basic Oxygen Furnace/Steelmaker (BOS)* and continuous casting methods.
- More recently, **computer-controlled** manufacturing has increased the efficiency and reduced the cost of steel production.

Main families of structural members

- In steel construction, there are 2 main families of structural members.
 1. *Hot-rolled shapes and members built up of plates* which is more familiar group.
 2. *Cold formed from steel sheet*, strip, plate, or at bar in roll-forming machines or by press brake or bending brake operations which is *less familiar but of growing importance*.

Oldest use of cold-formed steel products

- Corrugated sheets have been used in building construction **since about 1784**.
 - This is one of the oldest types of cold-formed steel products.
- Corrugated steel sheets are frequently used for roofing and siding in buildings because the sheets are strong, lightweight, and easy to erect.
- In many cases, they are used as **shear diaphragms** to **replace conventional bracing** and to stabilize entire structures or individual members such as columns and beams.

Advantages of Cold-formed steel

1. As compared with thicker hot-rolled shapes, cold-formed **light members** can be manufactured for relatively **light loads and/or short spans**.
2. Unusual sectional configurations can be produced **economically** by cold-forming operations, and consequently ***favorable strength-to-weight ratios*** can be obtained.
3. Nestable sections can be produced, allowing for compact **packaging and shipping**, as well as for **developing efficient structural applications**.

Advantages of Cold-formed steel

4. Load-carrying panels and decks can provide useful surfaces for floor, roof, and wall construction, and in other cases they can also provide enclosed cells for electrical and other conduits.
5. Load-carrying panels and decks not only withstand loads normal to their surfaces, but they can also act as shear diaphragms to resist force in their own planes if they are adequately interconnected to each other and to supporting members.

Qualities of *cold-formed steel* compared to other materials

- Lightness
- High strength and stiffness
- Ease of prefabrication and mass production
- Fast and easy erection and installation
- Substantial elimination of delays due to weather
- More accurate detailing
- Non-shrinking and non-creeping at ambient temperatures
- Formwork unneeded
- Termite proof and rot proof
- Uniform quality
- Economy in transportation and handling
- Non-combustibility
- Recyclable material

Structural steel industry

- The structural steel industry consists of 4 components (*AISC 2008*) :-
 1. **Producers** of structural steel including hot-rolled structural shapes and hollow sections.
 2. **Service centers** that function as **warehouses** and provide limited preprocessing of structural material.
 3. Structural steel **fabricators** that prepare the steel for the **building** process.
 4. **Erectors** that construct steel frames on the project site.

Construction engineers

- Civil and construction engineers will primarily interact with the **service centers** to determine the availability of products required for a project, the **fabricators for detail design** drawings and preparation of the product, and the **erectors** on the job site.

Steel alloys

- Currently, **steel and steel alloys** are used widely in civil engineering applications.
- In addition, **wrought iron** is still used on a smaller scale for **pipes**, as well as for general **blacksmith work**.
- **Cast iron** is used for pipes, hardware, and machine parts **not** subjected to **tensile** or **dynamic** loading.

Steel products

- Steel products **used in construction** can be classified as follows:

1. Structural steel produced by continuous casting and **hot rolling** for large structural shapes, plates, and sheet steel.

2. Cold-formed steel produced by cold-forming of sheet steel into desired shapes.

Steel ...

- 3. Fastening products** used for structural connections, including bolts, nuts and washers.
- 4. Reinforcing steel** (rebars) for use in concrete reinforcement.
- 5. Miscellaneous** products for use in such applications as **forms**.

Selecting products

- Civil and construction engineers rarely have the opportunity to **formulate steel with specific** properties.
 - Rather, they must **select existing products from suppliers.**
- Even the shapes for structural elements are generally restricted to those readily available from manufacturers.
- While specific shapes can be made to order, the **cost to fabricate low-volume members** is generally prohibitive.

Selecting ...

- Therefore the majority of civil engineering projects, with the **exception of bridges**, are designed using **standard steel types and structural shapes**.
- Bridges are a special case, in that the majority of bridge structures are fabricated from **plate steel rather than hot-rolled sections** or hollow structural sections (*AISC 2008*).

Selecting ...

- Even though civil and construction engineers are not responsible for formulating steel products, it is **beneficial** to understand how steel is **manufactured** and **treated** and how it **responds** to **loads** and environmental conditions.

Steel Production

- Steel production process consists of the following 3 phases:
 1. Reducing iron ore to pig iron.
 2. Refining pig iron (and scrap steel from recycling) to steel.
 3. Forming the steel into products.

Raw materials for production

Iron Ore



After mining, the ore is crushed and the iron is separated, then made into pellets, balls or briquettes using binders, such as water.

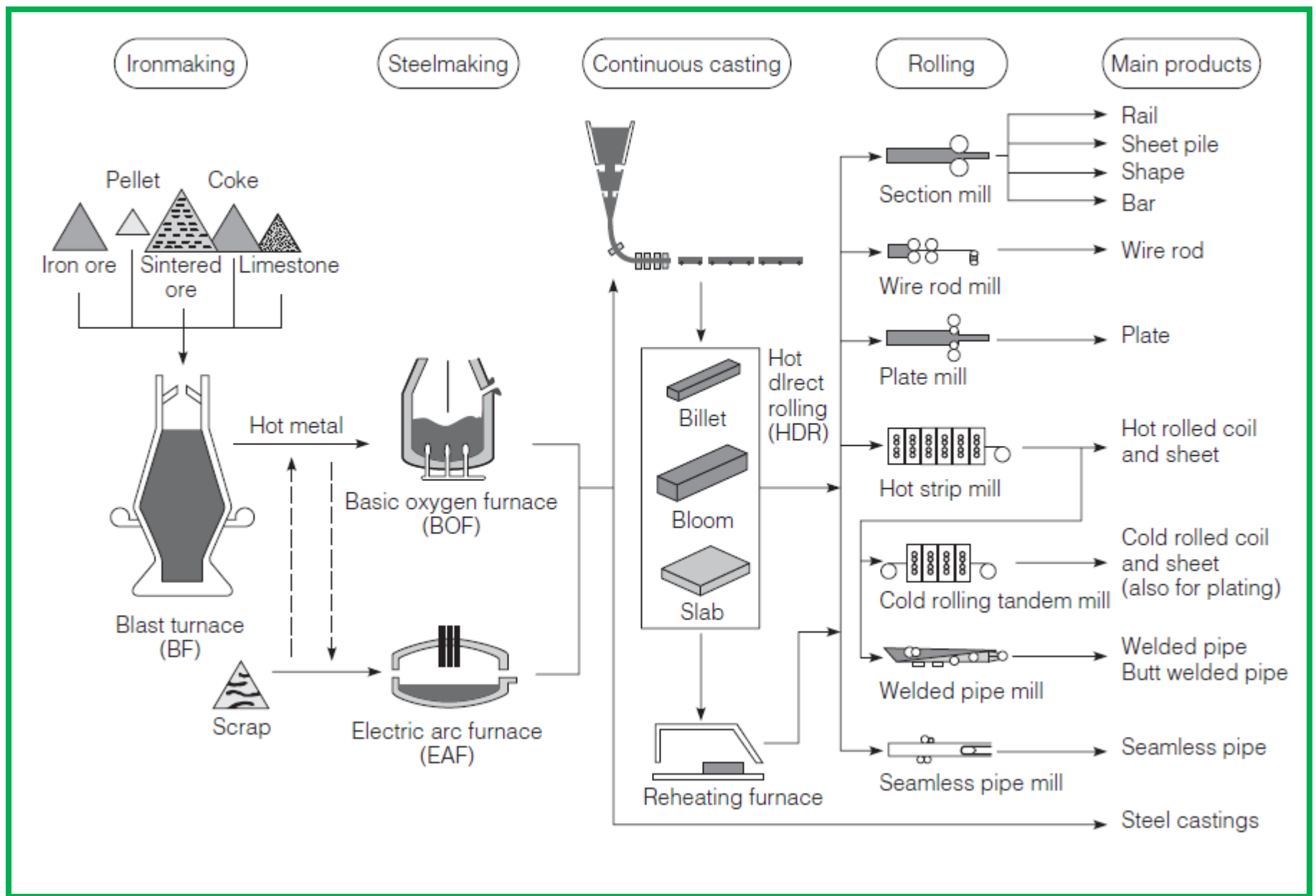
Limestone -----



Coke



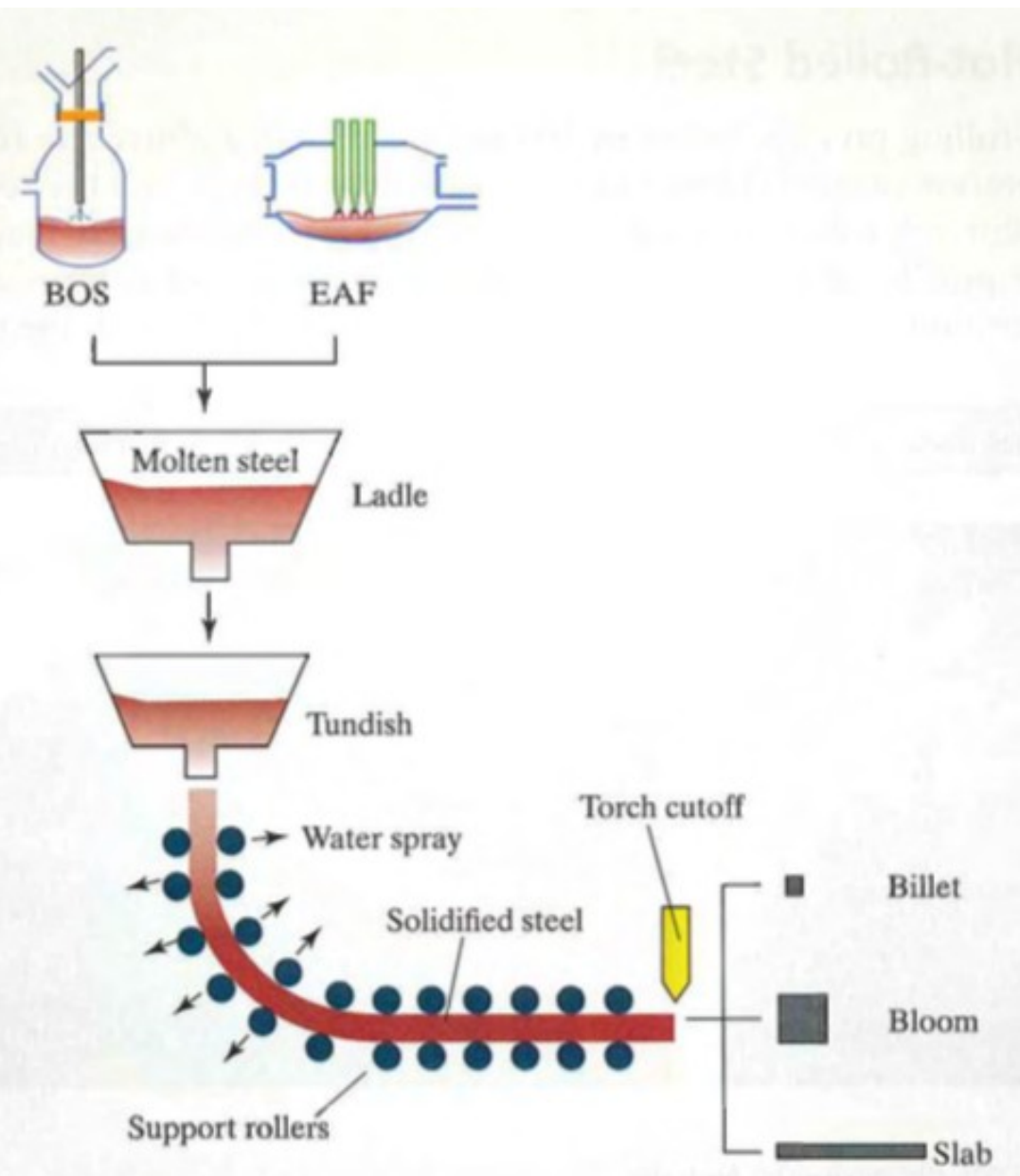
- When the metal is melted, limestone combines with impurities and floats to the top of the metal, forming *slag*.
- The slag can then be removed, purifying the iron.



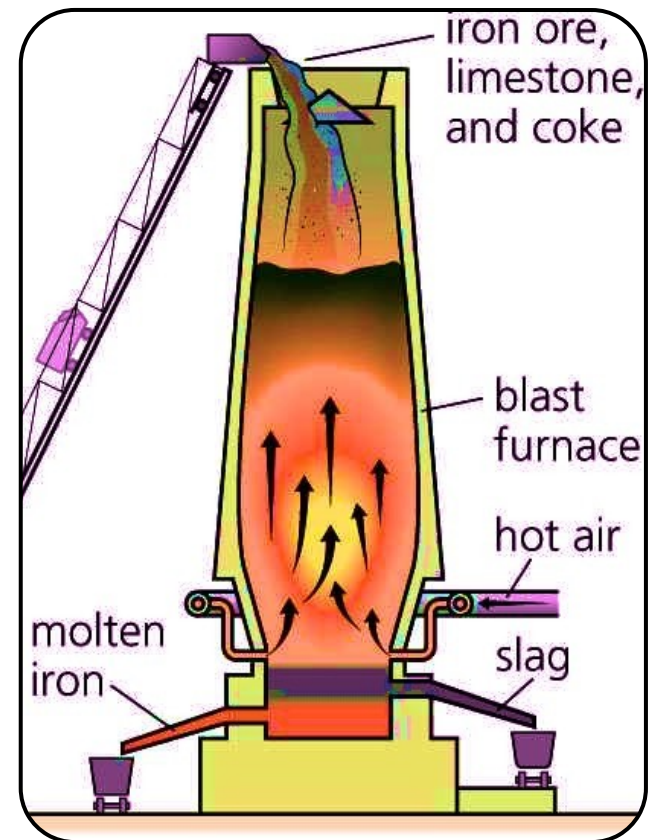
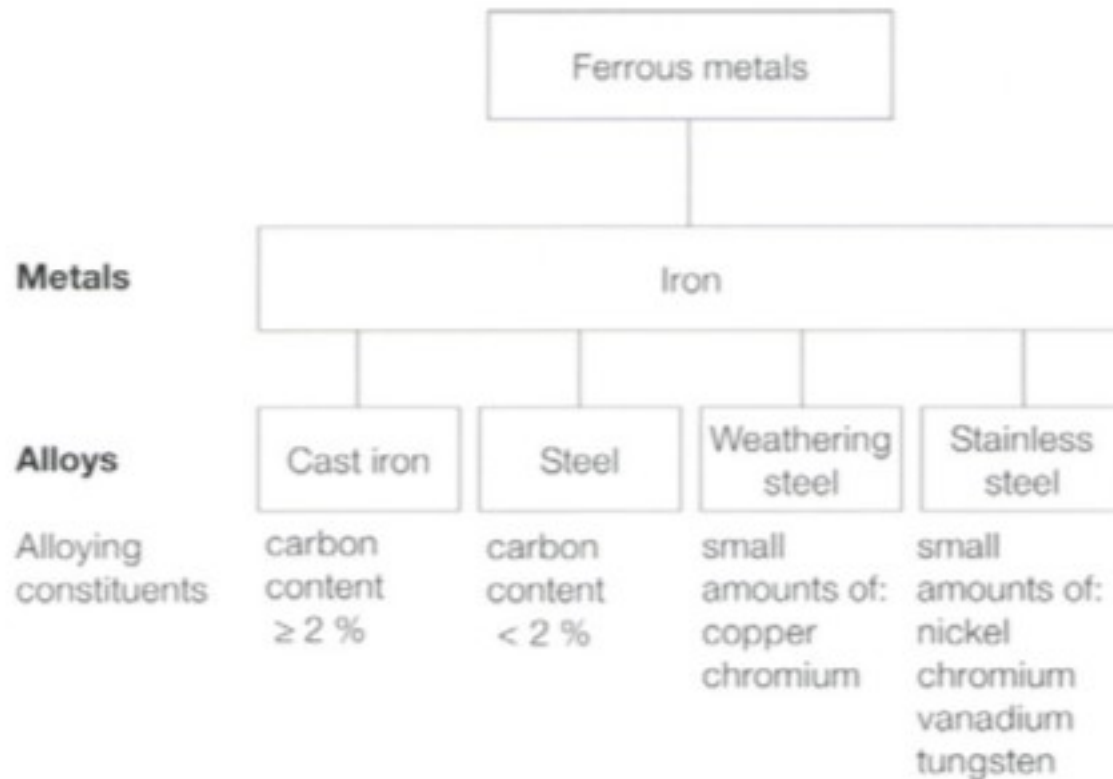
Conversion of raw material into different steel shapes

Molten steel from *BOS* and *EAF* is either poured through ladles to cast ingots (metal blocks used for further processing) or is continuously casted into solidified semi-finished products like billets, blooms, or slabs, depending on the end-use of the product and are subsequently processed in finishing mills.

Billets are lengths of metal with a square or round cross section with an area less than 230 cm². Billets are hot-rolled into bars and wires. Blooms have cross-sectional areas larger than billets and go through hot-rolling process to produce different structural shapes. Slabs on the other hand, are flat and wide rectangular metal sheets and are processed into sheet metal, plates, pipes, and tubes. Structural steel with required shapes is then produced through hot-rolling and cold-formed processes. **Continuous casting**



Continuous casting of steel



Types of furnaces

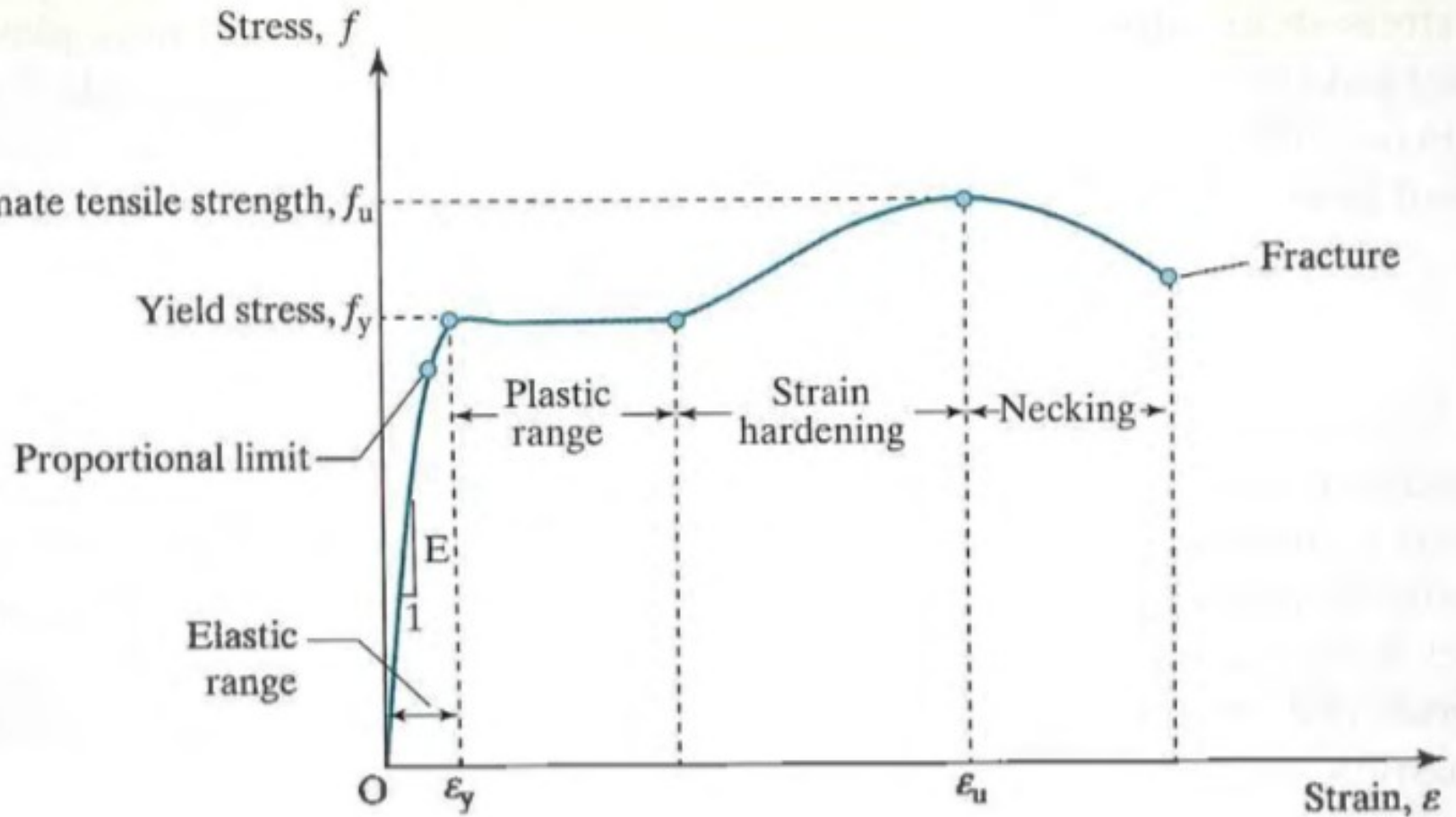
- Two types of furnaces are used for refining pig iron to steel:
 1. **Basic Oxygen Furnace/Steelmaker (*BOS*)**
 2. **Electric Arc Furnace (*EAF*)**
- The *BOS* remove **excess carbon** by reacting the carbon with oxygen to form gases.
 - The process is continued until all impurities are removed and the desired carbon content is achieved.
- *EAF* use an electric arc between carbon electrodes to **melt and refine the steel**.

Cold-formed steel

- Cold-formed steel is produced from sheets or **coils of hot rolled steel** which is formed into shape either through press-braking blanks sheared from sheets or coils, or **more commonly, by roll forming the steel through a series of dies at room temperature.**
 - No heat is required to form the shapes (unlike hot-rolled steel), and thus the name *cold-formed* steel.
- Cold-formed steel members and other products are **thinner, lighter, and easier** to produce, and typically **cost less** than their hot-rolled counterparts.

Cold-formed ...

- Steel sheets used to produce *cold-formed* steel sections are generally 0.378 mm to about 6.35 mm.
- Cold-formed steel sections are usually used for *light-weight* and *short-span structures*, which require better *durability* and *dimension precision*.
- More precise dimension sections can be achieved in cold-formed sections compared to *hot-rolled* steel products as the *hot-rolled* steel members tend to *shrink after cooling*.



Idealized stress-strain curve for structural steel

Cold-formed ...

- The large deformations caused by the cold-forming process results in local ***strain-hardening at the corners.***
 - The plastic deformation of the steel results in strain-hardening at the bends that **increases the yield strength**, tensile (*ultimate*) strength and hardness but **reduces ductility**.
- Strain hardening can almost **double** the **yield strength** and increase the tensile strength by 40%.

Standard production method

- Regardless of the refining process, the molten steel, with the desired chemical composition, is either cast into **ingots** (**large blocks of steel**) or **cast continuously** into a desired shape.
- Continuous casting with hot rolling is becoming the **standard production method**, since it is more **energy efficient** than casting ingots, as the ingots must be **reheated** prior to shaping the steel into the final product.

Standard ...

- Cold-formed steel used for steel framing members is predominately manufactured from scrap steel using either *EAF* or *BOS* to cast slabs.
- The slabs are passed through a machine with a series of **rollers** that **reduce the slab** into thin sheets of the desired **thicknesses**, **strengths** and other **physical properties**.
- The sheets are sent through a **hot-dipped galvanizing** process and then rolled into coils that weigh approximately **13 tons**.

Standard ...

- The steel used in light gauge members is manufactured to *ASTM* standard *A1003* and is ***metallic-coated with zinc or aluminum-zinc alloy to protect against corrosion.***
- The *thickness* of the *metallic coating* can be varied, depending on the *severity* of the environment in which the members will be placed.
- Or, in protected, noncorrosive environments, other coatings may also be used.

Standard ...

- Minimum thicknesses of base sheet metal (not including the metallic coating) for light gauge steel framing members.
- Though still used in common parlance, **gauge numbers are no longer included in industry standard specifications** due to a lack of consistency in their translation to actual thicknesses.
- Cold-formed steel was formerly known as **“light gauge” steel**; however, the reference nomenclature **“gauge” became obsolete** with the adoption of a Universal Designator System for all generic cold-formed steel framing members in 2000.

Minimum Thickness of Steel Sheet

Nominal Gauge	Loadbearing Members	Nonloadbearing Members
10	0.118" (3.00 mm)	
12	0.097" (2.45 mm)	
14	0.068" (1.72 mm)	0.068" (1.72 mm)
16	0.054" (1.37 mm)	0.054" (1.37 mm)
18	0.043" (1.09 mm)	0.043" (1.09 mm)
21	0.033" (0.84 mm)	0.033" (0.84 mm)
20		0.030" (0.75 mm)
22		0.024" (0.60 mm)
25		0.018" (0.45 mm)
28		0.015" (0.38 mm)

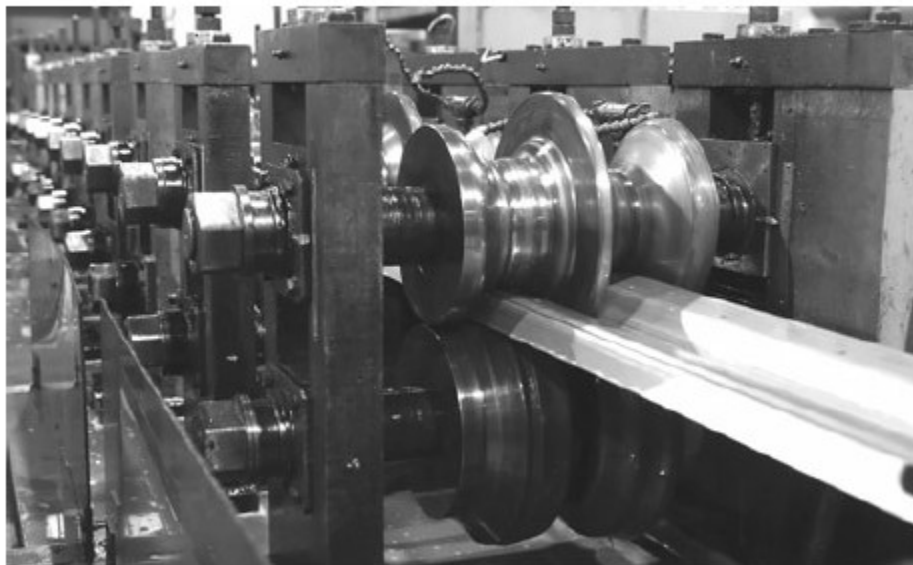
Shaded figures indicate the most commonly used

Structural Grades of Steel Used in Cold-Formed Products

Type	Structural Grade ¹	Designation US	Designation Metric
H – high ductility	33 (230)	ST33H	ST230H
	50 (340)	ST50H	ST340H
L – low ductility	33 (230)	ST33L	ST230L
	50 (340)	ST50L	ST340L
NS – nonstructural	33 (230)	NS33	NS230

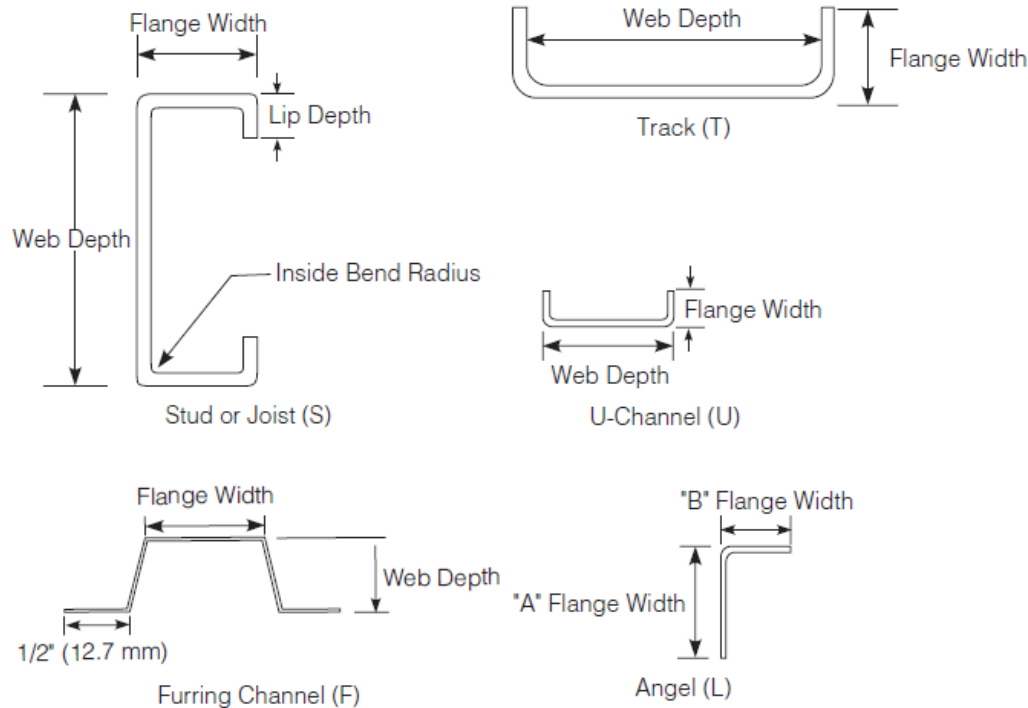
¹yield strength, ksi (kPa)

Roll-forming of cold-formed steel



Standard ...

- The **strength** and **stiffness** of a member depend on its **shape** and **size**, as well as the **strength** and **thickness** of sheet metal used in its manufacture.
- Steel with ***yield strengths*** of both 230 and 350 MPa is used.
- Light gauge steel members are identified using a **standard nomenclature** including member **depth**, a **letter** designation for **shape**, member **width**, and metal **thickness**.



Generic cold-formed steel framing shapes

- For example, a **600S162-54** member is a 6.00-inch-deep ("600") **stud/joist** section ("S"), 1.62 inches wide ("162"), made from 54-mil-thick sheet metal ("54") – (**mil is thousandths of an inch**).

Generic shapes covered by the **Universal Designator System**: The designator consists of 4 sequential codes. The 1st code is a 3 or 4-digit number indicating the member web depth in 1/100 inches. The 2nd is a single letter indicating the type of member, as follows:

S = Stud/joist framing member with stiffening lips

L = Angle or L-header

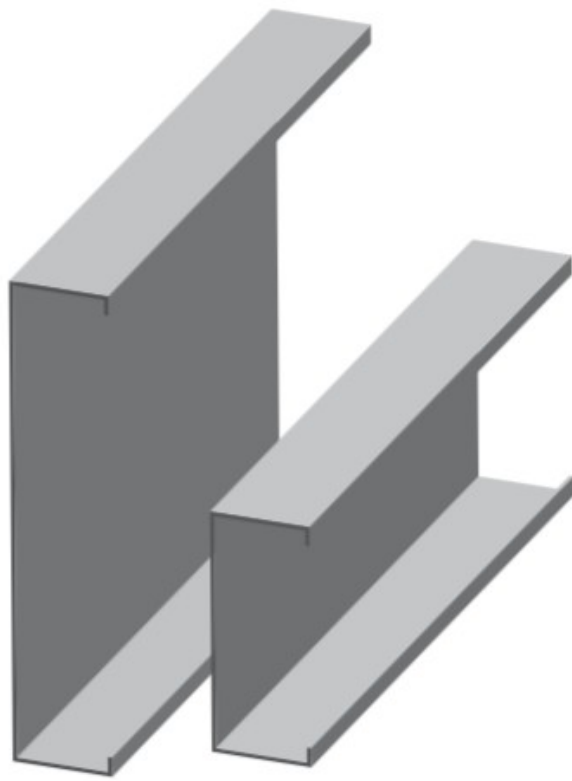
F = Furring channels

U = Cold-rolled channel

T = Track section

The 3rd is a 3-digit numeral indication flange width in 1/100 inches followed by a dash.

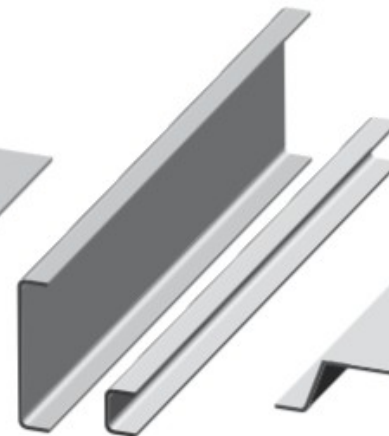
The 4th is a 2-3-digit numeral indicating the base steel thickness in 1/1000 inch (mils).



STUD/JOIST SECTION



TRACK SECTION



CHANNEL SECTION



FURRING CHANNEL

- For wall, floor, and roof framing, the steel is formed into *C-shaped stud/ joist sections*.
- *Track sections* are used for top and bottom plates. They are slightly oversized so that *stud/ joist* members can nest into them.
- *Channel sections* and *furring channels* are used for lighter bracing and framing tasks.
- Other specialized shapes are also available.

Standard light gauge steel shapes and sizes

Cold-Formed Member	Example Designation	Available Depths	Available Widths
S: Stud/ Joist Section	600S162-54	1.625", 2.5", 3.5", 3.625", 4", 5.5", and 6"–16" 41, 64, 90, 92, 102, 140, and 152–406 mm	1.25"–2.5" 32 mm–64 mm
T: Track Section	362T125-30	Same as above	1.25"–2" 32 mm–51 mm
U: Channel Section	250U050-54	0.75"–2.5" 19 mm–64 mm	0.5" 13 mm
F: Furring Channel	087F125-43	0.875"–1.25" 22 mm–32 mm	1.25"–2.5" 32 mm–64 mm

Application of Cold-formed steel

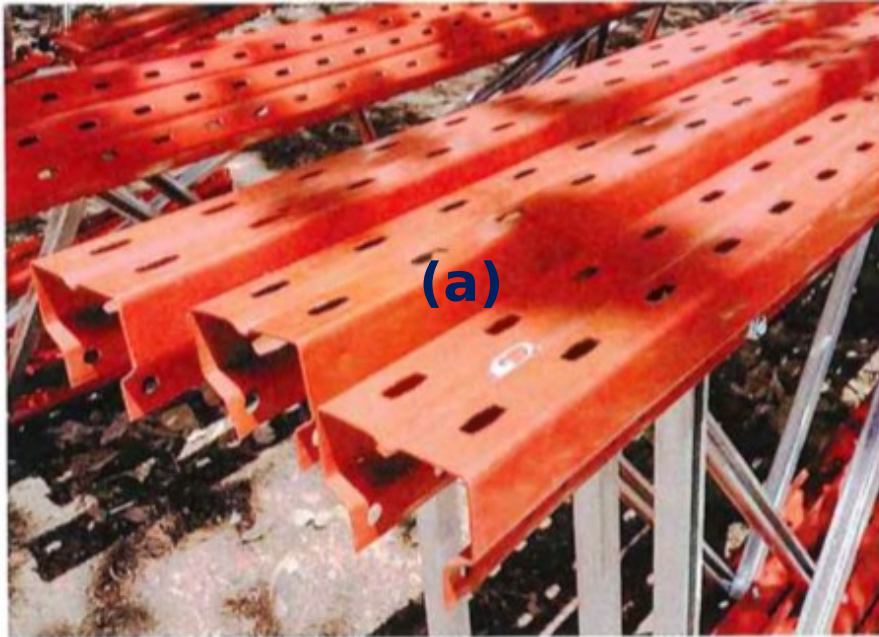
- Cold-formed steels are used as structural framing members or in **panels** and **decks**.
- Cold-formed steel sections are used in **car bodies**, **railway coaches**, various types of **equipment**, **storage racks**, **grain bins**, **highway products**, **transmission towers**, **transmission poles**, **drainage facilities**, and **bridge construction**.
- They are also used as **joists**, **purlins**, **studs**, and **decks** in high-rise structures, along with hot-rolled sections as a main framing system.
- Cold-formed sections are also widely used in **roof** and **floor decks** and **wall panels**, which carry load as well as provide a surface to **attach flooring** and **roofing materials**.



Building frame with hot-rolled steel used as columns and main beams and cold-formed steel used as purlins, girts, joists, and roof/wall cladding

Building composed
entirely of cold-formed
steel sections

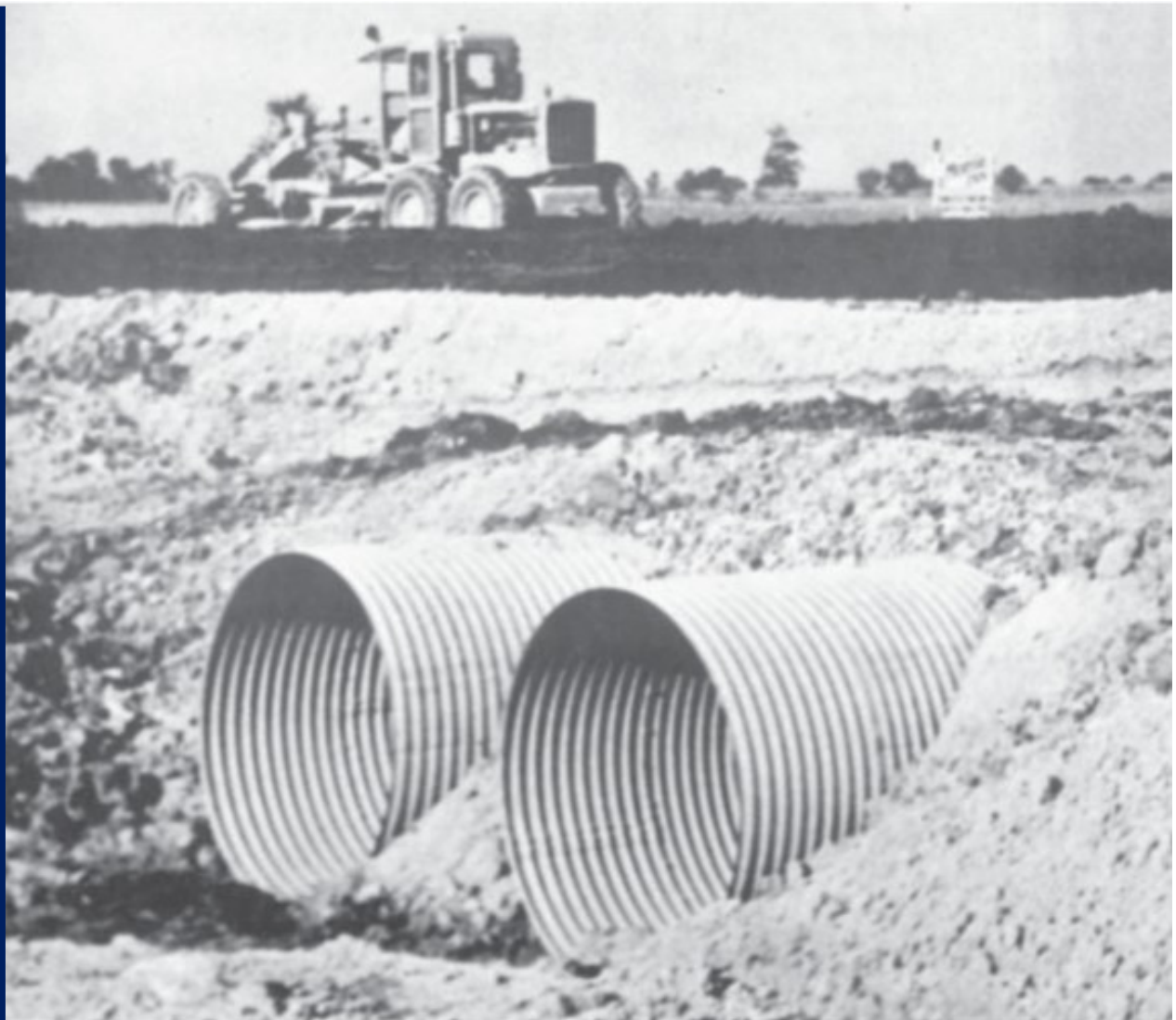




(a) Cold-formed sections used for storage racks

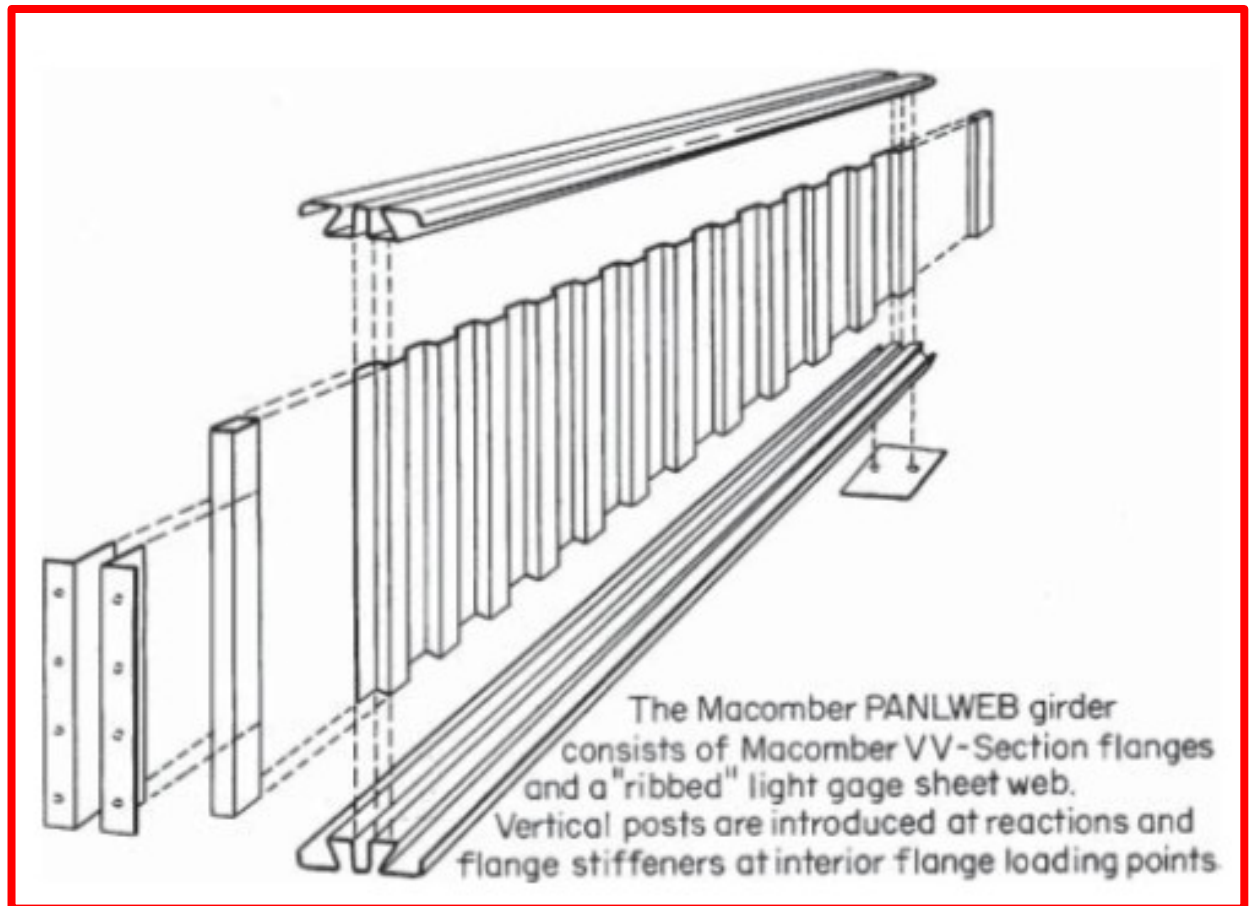
(b) Cold-formed steel used in floor decks and storage racks

- Corrugated steel pipe of galvanized sheets has long been used in drainage structures for railways, highways, and airports.
- Corrugated steel products have been used for retaining walls, guardrails, conveyor covers, aerial conduits, and other purposes.

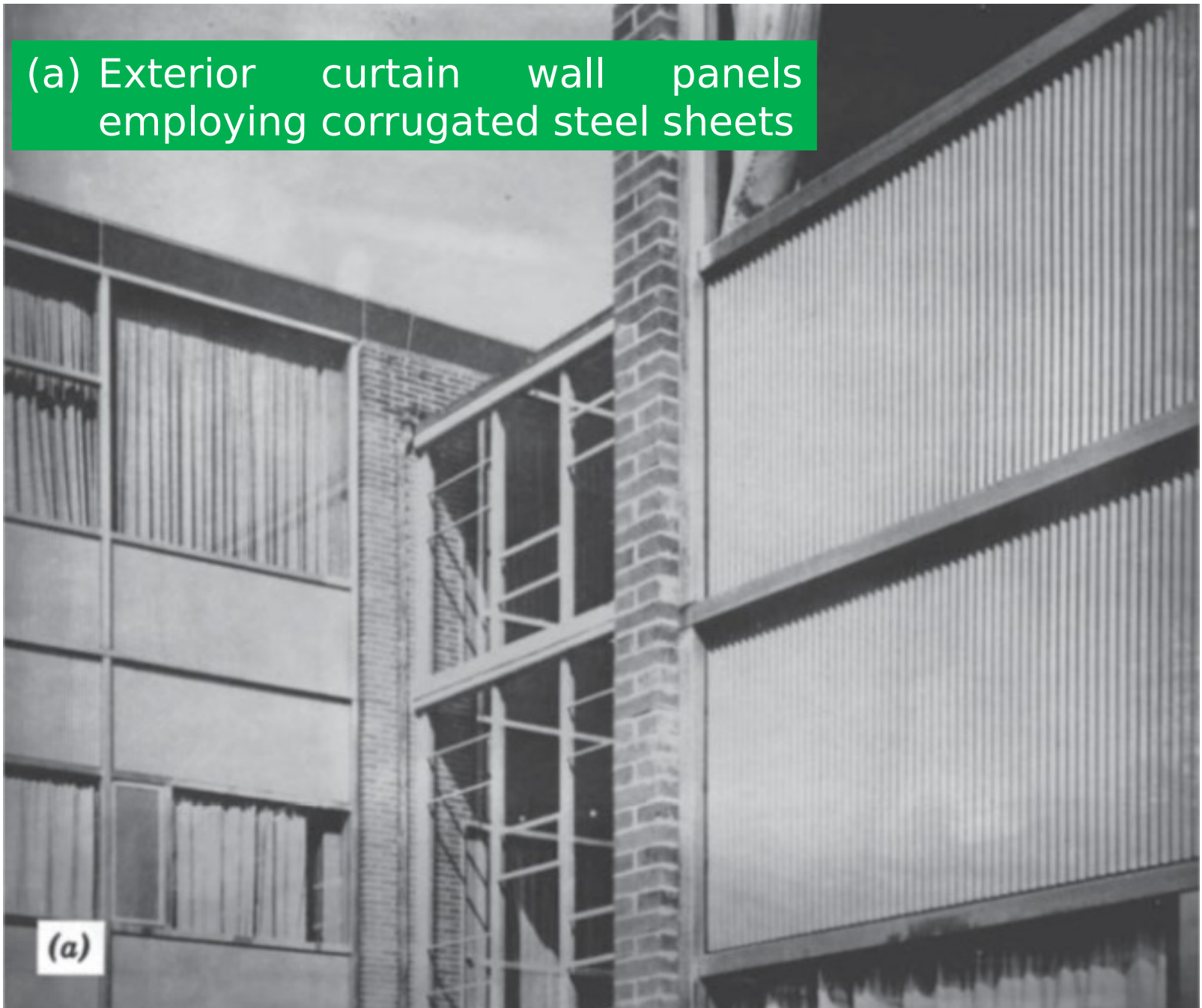


- During recent years, corrugated sheets have been used in flooring systems for buildings and bridge construction.
- These products have also been used as web elements for built-up girders in order to increase web stiffness instead of using a relatively thicker plate or a thin web with stiffeners.

The Macomber Panlweb girder consists of 1.9 – 3.8 mm corrugated web for depths of 0.51 – 1.02 m.



(a) Exterior curtain wall panels
employing corrugated steel sheets





(b) Frameless stressed-skin construction



Standardized building made of fabricated rigid frame with *cold-formed* sections for girts, purlins, roofs, and walls.

Improved structural properties

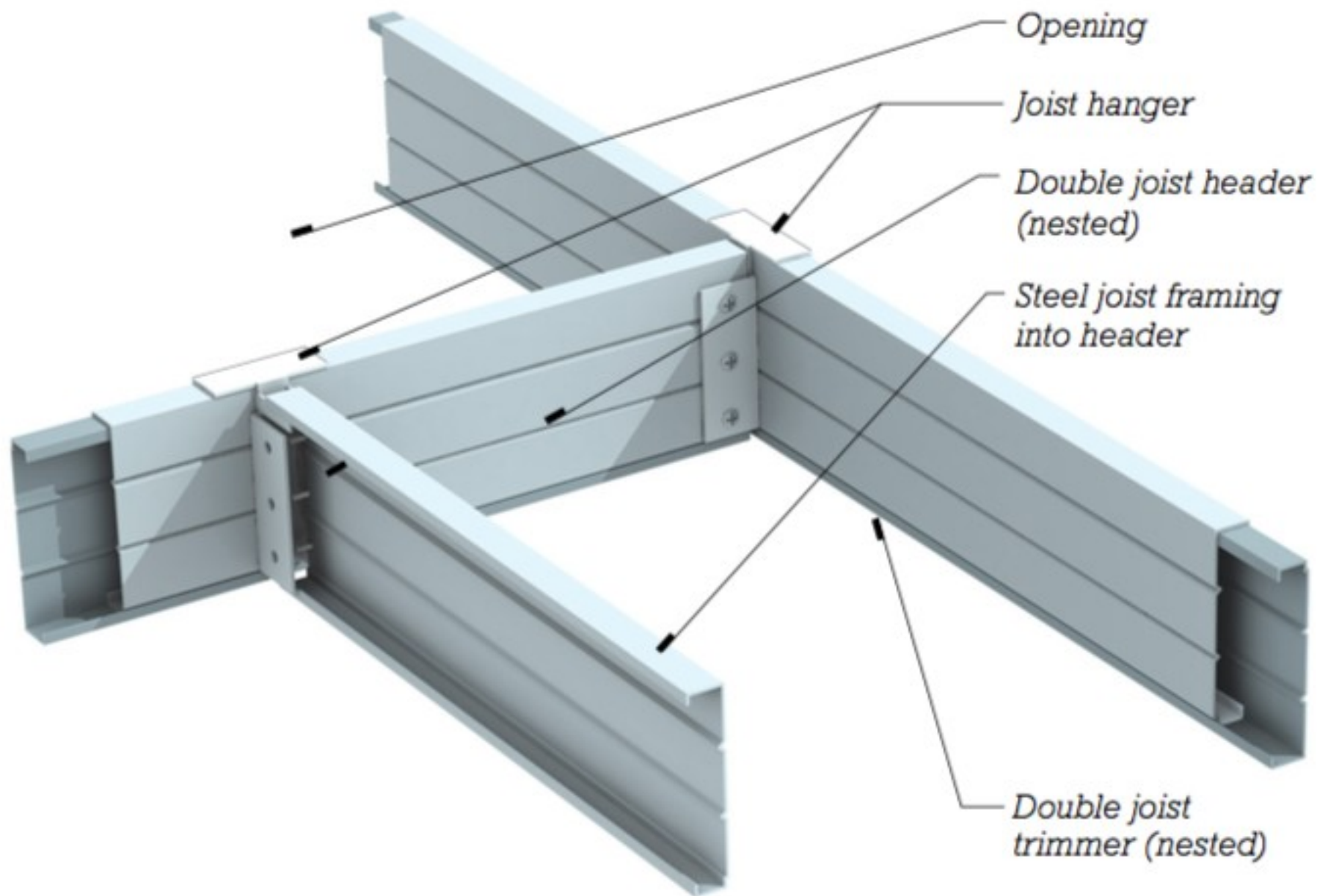
- Some manufacturers produce specially formed member types with improved structural properties.
- For example, the cross-sectional profile of a *stud/joist section* may be altered to enhance its **strength** and **stiffness**.
- Or, studs may be passed through rollers that produce a dense array of **dimples** in the formed metal.
- The additional cold working of the metal that occurs during this process and the patterning of the surface produce a stud with greater **strength and stiffness without increasing metal thickness**.

Member connection

- Light gauge steel members are usually joined with *self-drilling screws*, which drill their own holes and form helical threads in the holes as they are installed.
- Driven rapidly by handheld electric or pneumatic tools, these screws are plated with cadmium or zinc to resist corrosion, and they are available in an assortment of diameters and lengths to suit a full range of connection needs.

Member ...

- **Welding** is often employed to assemble panels of light gauge steel framing that are prefabricated in a factory, and is sometimes used on the building site where **stronger connections** are needed.
- Other fastening techniques include hand-held clinching devices that join members without screws or welds and **pneumatically driven pins**, analogous to nails in wood light frame construction, that penetrate the members and hold by friction.



Cold-formed Steel Framing and the Building Codes

- Cold-formed steel framing members are **noncombustible** and can be used in any building code construction type as long as they **meet necessary fire resistance rating requirements**.
- When unprotected, light gauge steel framing members will lose their strength and stiffness rapidly when exposed to the heat of fire.
- However, with suitable **protection**, such as **gypsum board** or **plaster**, loadbearing light gauge steel assemblies can readily **meet 2-hour fire resistance** rating requirements.

Cold-formed Steel ...

- In its *International Residential Code (IRC)* for One- and Two-Family Dwellings, the International Code Council has incorporated prescriptive requirements for steel-framed residential construction.
- In many cases, these requirements, with their structural tables and standard details, allow builders to design and construct Cold-formed steel-framed houses without having to employ an engineer or architect, just as they are able to do with wood light frame construction.

Metals in architecture

- Metals are generally ductile, meaning that they can be hammered thin or drawn into wires.
- They can be liquefied by heating and will resolidify as they cool.
- Most metals corrode by oxidation.
- Metals include the strongest building materials presently in common use, although stronger materials based on carbon or aramid fibers are beginning to appear more frequently in building construction applications.

Metals in ...

- Because iron ore is an abundant mineral and is relatively easy to refine, ferrous metals tend to be **much less expensive than nonferrous ones**.
 - The ferrous metals are also the strongest, but most have a tendency to rust.
- Nonferrous metals in general are considerably more expensive on a volumetric basis than ferrous metals, but unlike ferrous metals, most of them form thin, tenacious oxide layers that protect from further corrosion under normal atmospheric conditions.
 - This makes many of the nonferrous metals valuable for finish components of buildings.
- Many of the nonferrous metals are also easy to work and attractive to the eye.

Modifying the Properties of Metals

- A metal is seldom used in its chemically pure state.
- Instead, it is mixed with other elements, primarily other metals, to modify its properties for a particular purpose.
- Such mixtures are called **alloys**.
 - An **alloy** that combines copper with a small amount of tin is known as bronze.
 - A very small, closely controlled amount of **carbon** mixed with iron *makes steel*.
- In both of these examples, the **alloy** is stronger and harder than the elemental metal that is its primary ingredient.
- Some of these have higher strengths, and some form self-protecting oxide layers because of the influence of the alloying elements they contain.

Heat treatment

- The properties of many metals can also be changed by *heat treatment*.
- Steel that is *quenched*, that is, heated red-hot and then *plunged in cold water*, becomes *much harder but brittle*.
- Steel can be *tempered* by heating it to a **moderate degree** and cooling it more slowly, making it both **hard and strong**.
- Steel that is brought to a **very high temperature** and then cooled very slowly, a process called **annealing**, will become softer, easier to work, and less brittle.

Cold working

- *Cold working* is another way of changing the properties of a metal.
- When steel is beaten or rolled thinner at room temperature, its crystalline structure is altered in a way that makes it much stronger, though also somewhat more brittle.
- The highest-strength metals used in construction are steel wires and cables used to prestress concrete.
- Their high strength (about 4 times that of normal structural steel) is the result of drawing the metal through smaller and smaller orifices to produce the wire, a process that subjects the metal to a *high degree of cold working*.

Cold working

- Cold-rolled steel shapes with substantially higher strengths than hot-rolled structural steel are used as *reinforcing* and as components of *open-web joists*.
- The effects of **cold working** are easily **reversed** by **annealing**.
- Hot rolling, which is, in effect, a **self-annealing** process, **does not increase the strength of metal**.
- To protect them and enhance their appearance, metals are frequently finished with nonmetallic coatings such as paints, lacquers, organic coatings, porcelain enamel, and thermosetting powders.

Fabricating Metals

- Metals can be shaped in many different ways.
- Casting is the process of pouring molten metal into a shaped mold; the metal retains the shape of the mold as it cools.
- Rolling, which may be done either hot or cold, forms the metal by squeezing it between a series of shaped rollers.
- **Extrusion** is the process of squeezing heated, but not molten, metal through a **shaped die** to produce a long metal piece with a shaped profile matching the cutout in the die.
- **Forging** involves heating a piece of metal until it becomes soft, then beating it into shape.

Fabricating ...

- **Forging** was originally done by hand with a blacksmith's forge, hammer, and anvil.
- Now most forging is done with powerful hydraulic machinery that forces the metal into shaped dies.
- **Stamping** is the process of squeezing sheet metal between two matching dies to give it a desired shape or texture.
- **Drawing** produces wires by pulling a metal rod through a series of progressively smaller orifices in hardened steel plates until the desired diameter is reached.

Effects of forming processes

- These forming processes have varying effects on the strength of the resulting material: **Cold drawing** and cold rolling will **harden** and **strengthen** many metals.
- **Forging** imparts a *grain orientation* to the metal that closely follows the shape of the piece for improved structural performance.
- **Casting** tends to *produce somewhat weaker metal* than most other forming processes, but it is useful *for making elaborate shapes* (such as lavatory faucets) that could not be manufactured economically in any other way.
- Recent developments in steel casting enable the production of castings that are as strong as rolled steel shapes.

Other machine shaping

- Metals can also be shaped by **machining**, which is a process of cutting unwanted material from a piece of metal to produce the desired shape.
- Among the most common machining operations is **milling**, in which a rotating cutting wheel is used to cut metal from a workpiece.
- To produce cylindrical shapes, a piece of metal is rotated against a stationary cutting tool in a **lathe**.
- Holes are produced by **drilling**, which is usually carried out either in a **drill press** or a **lathe**.
- Screw threads may be produced in a hole by the use of a helical cutting tool called a **tap**, and the external threads on a steel rod are cut with a **die**.

Stainless steel

- Stainless steel, made by alloying steel with other metals, primarily chromium and nickel, forms a self-protecting oxide coating that makes it highly resistant to corrosion.
- It is harder to form and machine than mild steel and is more costly.
- It is available in attractive finishes that range from matte textures to a mirror polish.
- Stainless steel is frequently used in the manufacture of fasteners, roofing and flashing sheet, hardware, railings, and other ornamental metal items.

Stainless ...

- Stainless steel is available in different alloys distinguished, most importantly, by their level of corrosion resistance.
- *Type 304 stainless* steel is the type most commonly specified and provides adequate corrosion resistance for most applications.
- *Type 304 stainless* steel may also be referred to as Type 18-8, where the two numbers refer to the percentages of chromium and nickel, respectively, in this alloy.
- *Type 316 stainless* steel, with higher nickel content and the addition of small amounts of molybdenum, is more corrosion-resistant than Type 304.
- It is specified for use in marine environments where salt-laden air can lead to the accelerated corrosion of less resistant stainless steel alloys.

Stainless ...

- *Type 410 stainless* steel has a lower chromium content and is less corrosion-resistant than the 300 series alloys. However, this alloy also has a different metallic crystal structure that, unlike the 300 series alloys, allows it to be hardened through heat treatment.
- *Self-drilling*, self-tapping stainless steel fasteners, whose threads must be tough enough to cut through structural steel or concrete, are frequently made of hardened *Type 410 stainless* steel.

High-performance steel: *Weathering Steel*

- *Weathering Steel* is added a little alloy such as copper(Cu), chromium(Cr), and nickel(Ni) during the steel making.
- Actually Steel making looks like a COOKING in our kitchen. Such as put some spices into the curry.
- We can make a variety of curry by changing some spices appropriately.

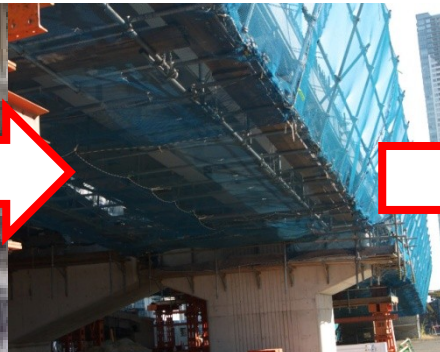
Constructed Steel Bridges in Nairobi



Ordinary
Steel



Re-painting Work of Steel

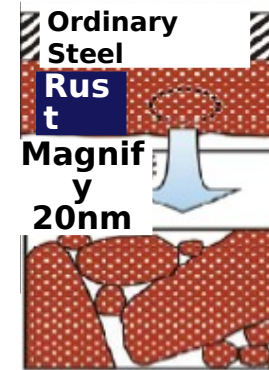
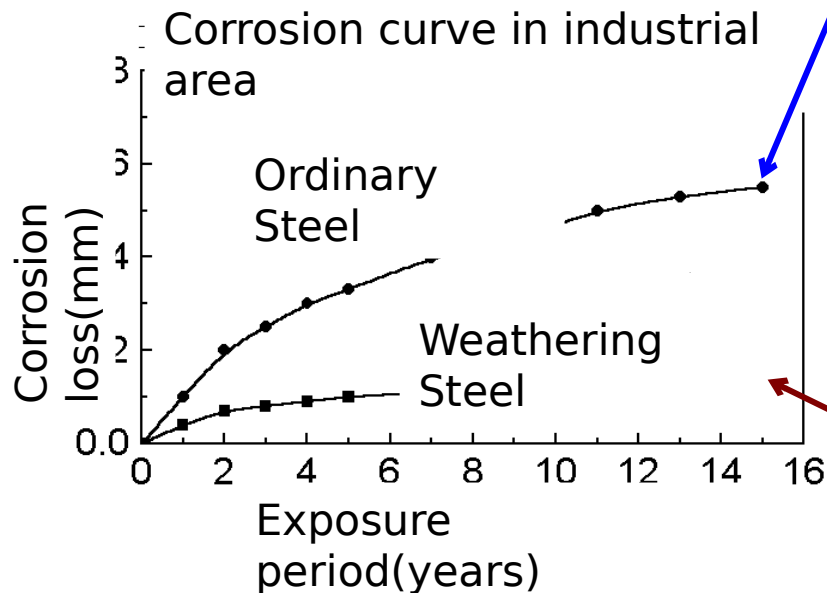


Every **10-15**
years



**Weathering
Steel**

Weathering Steel and Ordinary Steel



Ordinary Steel

- Rust layer is **porous & fragile**.
- Corrosion speed does not slow down.



Weathering Steel

- Rust layer is **fine & tight**.
- Corrosion speed drastically slow down.

Application Examples in Africa



**Rusumo International Bridge
at the border of
Rwanda and Tanzania
(Completion, Jan 2015)**



**Volta River Bridge In
Ghana
(under Design)**



**Kampala Flyover In
Uganda
(Under Design)**



NIPPON STEEL & SUMITOMO METAL CORP. GROUP

Summary

- Structural steel used in construction industry is an iron alloy containing carbon in the range of 0.2-1.5% by weight and other elements.
- The *BOS* and *EAF* processes together account for 98% of the total steel produced in the world today.
- In the *BOS* process, pig iron and scrap iron are converted into steel by blowing pure oxygen over the molten iron from blast furnace. Lime-based fluxes are used to remove impurities in the form of slag.
- Structural and non-structural cold-formed steel members are manufactured from sheet steel in compliance with a certain standards such as *ASTM A1003/A1003M*.

Summary

- In the *EAF* process, scrap iron and lime are heated by means of an electric arc.
- Oxygen is blown into the furnace to remove other impurities from the iron.
- Most of the structural steel used in the construction industry falls under low-carbon (carbon content less than 0.25%) and medium-carbon steel (carbon content in the range of 0.3 to 0.6%) category.
- The increase in carbon content in steel increases its strength and toughness but adversely affects its ductility.

Summary

- Continuous casting, together with the hot-rolling process, is predominantly used in modern steel plants to produce desired steel sections for the construction industry. In the hot-rolling process, red-hot iron is squeezed through rollers into desired shapes.
- *Cold-formed steel* is produced by rolling or pressing thin steel sheets through rollers or press brakes at room temperature to produce lightweight steel sections.
- Hot-rolled sections are subjected to heat treatment, which involves heating and subsequent cooling of steel to enhance physical and mechanical properties of steel.

Summary

- The quenching process, which involves rapid heating of steel followed rapidly cooling, results in a very strong and hard steel surface. Ductility is enhanced when quench-hardened steel is reheated and allowed to cool slowly.
 - This process is called tempering.
- A tension test is used to determine the yield stress, ultimate tensile strength, stiffness, and ductility of steel.
 - The stress at which steel starts to yield is called yield stress. The corresponding strain at the yield stress is called yield strain.