# Metal Structures

# Lecture I

# Introduction

Contents

# Most important standards

Important for design projects and laboratories on first step of studies (Eurocodes, other standards):

General information:

EN 1990

Loads:

EN 1991-1-1

EN 1991-1-3

EN 1991-1-4

Steel structures:

EN 1993-1-1

EN 1993-1-5

EN 1993-1-8

EN 1993-1-10

Contact with other materials:

EN 1992-1-1

EN 1996-1-1

Another problems:

EN 1090-2

EN ISO 6520-1

EN ISO 5817

Another, presented or mentioned on lectures:

Loads:

EN 1991-1-2

EN 1991-1-5

EN 1991-1-6

EN 1991-1-7

EN 1991-3

EN 1991-3

EN 1991-4

Steel structures:

EN 1993-1-2

EN 1993-1-3

EN 1993-1-4

EN 1993-1-6

EN 1993-1-7

EN 1993-1-9

EN 1993-1-11

EN 1993-1-12

Steel structures:

EN 1993-2

EN 1993-3-1

EN 1993-3-2

EN 1993-4-1

EN 1993-4-2

EN 1993-4-3

EN 1993-5

EN 1993-6

Another, presented or mentioned on lectures:

Aluminum structures:

EN 1999-1-1

EN 1999-1-2

EN 1999-1-3

EN 1999-1-4

EN 1999-1-5

Another problems:

EN 1998-1

EN 1011

EN ISO 1944

EN 1337-6

ISO 2560

ISO 3580

ISO 3581

Another problems:

EN 10 025-2

EN 10 164

EN 13 001

EN 12 345

EN ISO 12 944

EN 14 399

EN 15 048

ISO 18 275

## Definitios

Steel - alloy, Fe + C + other ($C \leq 2{,}05$ %, $Fe \approx 98\%$);

Iron - chemical element Fe;

Iron ore - mixture, $Fe \approx 25 - 70\%$ + pollutions;

Pig iron - mixture, $C \approx 5$ % pollutions $\approx 5$ % $Fe \approx 90$ %;

Cast iron - alloy, Fe + C + other ($2{,}1\% \leq C \leq 4{,}3$ %);

Steel casting - steel without heat treating;

Aluminum - alloy, Al + other;

## History

About 3 300 BC, Egypt and Mesopotamia - beginning of using iron from meteorites; iron jewelry and weapons;

Photo: wiedzoholik.pl

About 2 800 BC, Mesopotamia - the oldest case of using iron from iron ore;

About 1 200 BC, Hetitian Kingdom (Asia Minor) - prevalence of using iron from iron ore; weapons and tools; beginning of Iron Age;

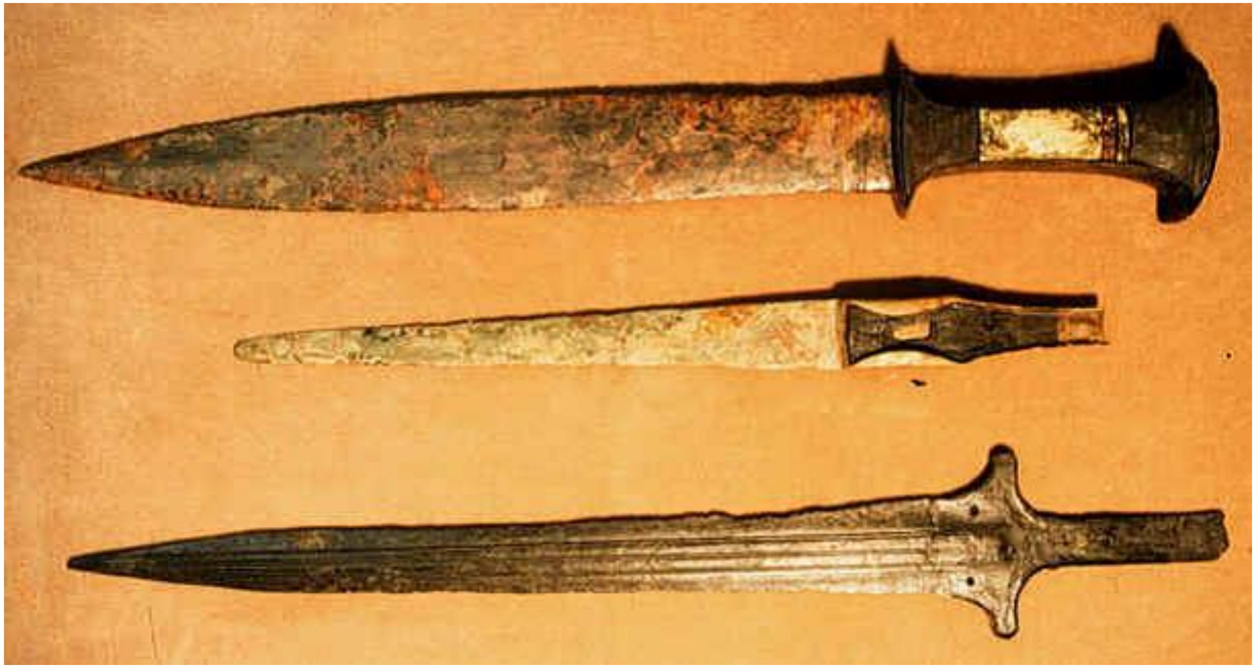


Photo: armieswiata.freehost.pl

Iron from meteorites ↔ iron from iron ore:

difference in proportions of isotopes and chemical composition.

Bloomery - only iron ore and coal, no additional air;

Blast furnace - additional air from bellows (blast air);

Modern blast furnace - coke instead coal;

Photo: wikipedia

Photo: oldindustry.org

Photo: wikipedia

About 50 AC, China - first blast furnace on the world;

About 1250 AC - first blast furnace in Europe;

1735 AC, England - first modern blast furnace on the world;

Photo: merryfarmer.net

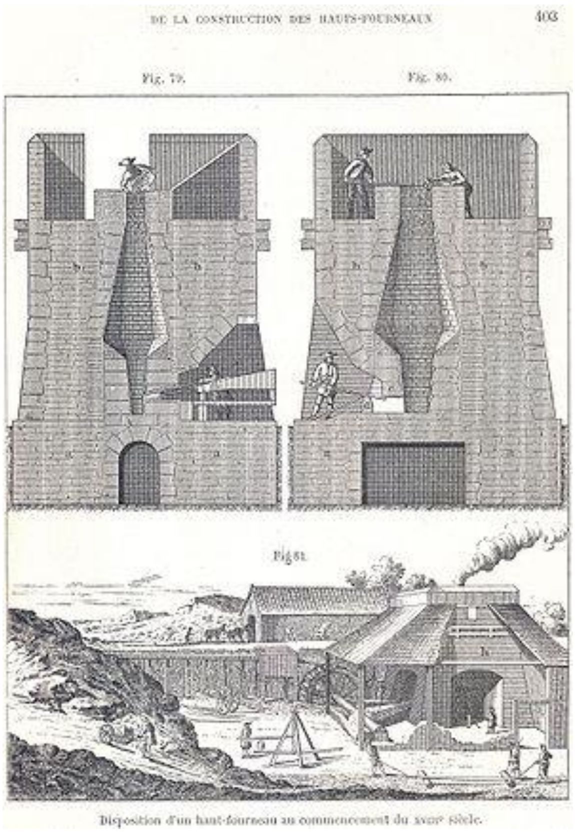



Photo: wow.com

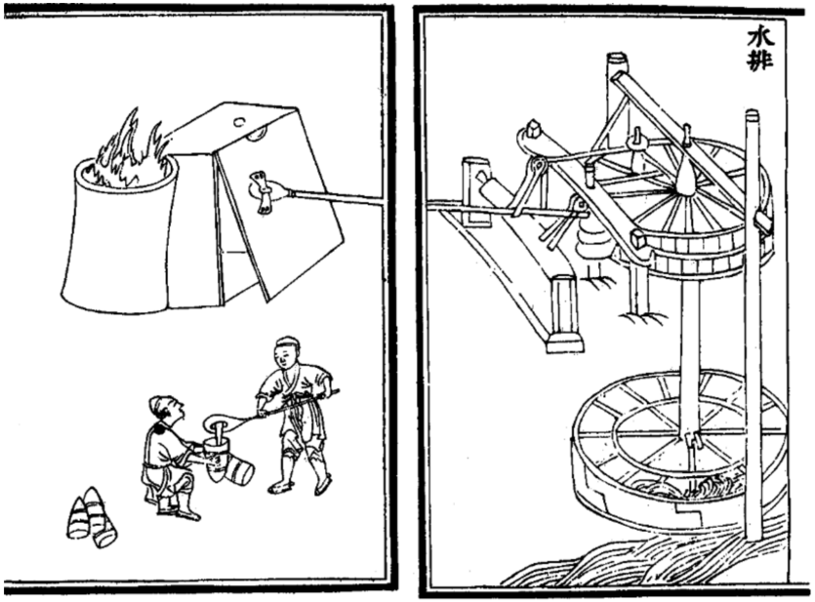



Photo: wikipedia

Iron from bloomeries is porous, of poor quality and with many impurities. It must be hammered to decrease amount of impurities (bloom iron → wrought iron) or melted (bloom iron → cast iron).

Photo: forumkowalskie.pl

Photo: avista.org

Photo: pinterest.com

In addition to weapons and tools, wrought / cast iron monuments were erected.

About 415 AC, Delhi - first stainless structure on the world.

Stainless is a side effect of the natural composition of the local iron ore.

Pillar is made of wrought iron.

Photo: wikipedia

Cast iron monuments:

Iron Pagoda, Ganlu, about 825 AC;

Iron Lion, Cangzhou, 953 AC;

Iron Pagoda, Yuquan, 1061 AC;

Photo: panoramio.com/rheins

Photo: messagetoeagle.com

1777-1781, Coalbrookdale, England - erection of iron (cast iron) bridge; considered as first iron structure on the world; symbolic beginnin of industry revolution.

Photo: wikipedia

1796, Ditherington Flax Mill - the first iron-framed industrial building in the world.

Photo: 8late.wordpress.com

Photo: ironbridge.blogspot.com

About 1825, The Commissioner's House of the Royal Naval Dockyard, Bermuda - the first iron-framed residential building in the world.

Photo: tripadvisor.co.uk

Photo: gotobermuda.com

1856, England - Henry Bessemer patented converter; mass production (5 t / 20 min) of high quality steel (steel casting);


Photo: wikipedia

1889, Paris – Eiffel Tower, steel riveted structure; first structure in the world higher than 300 m.

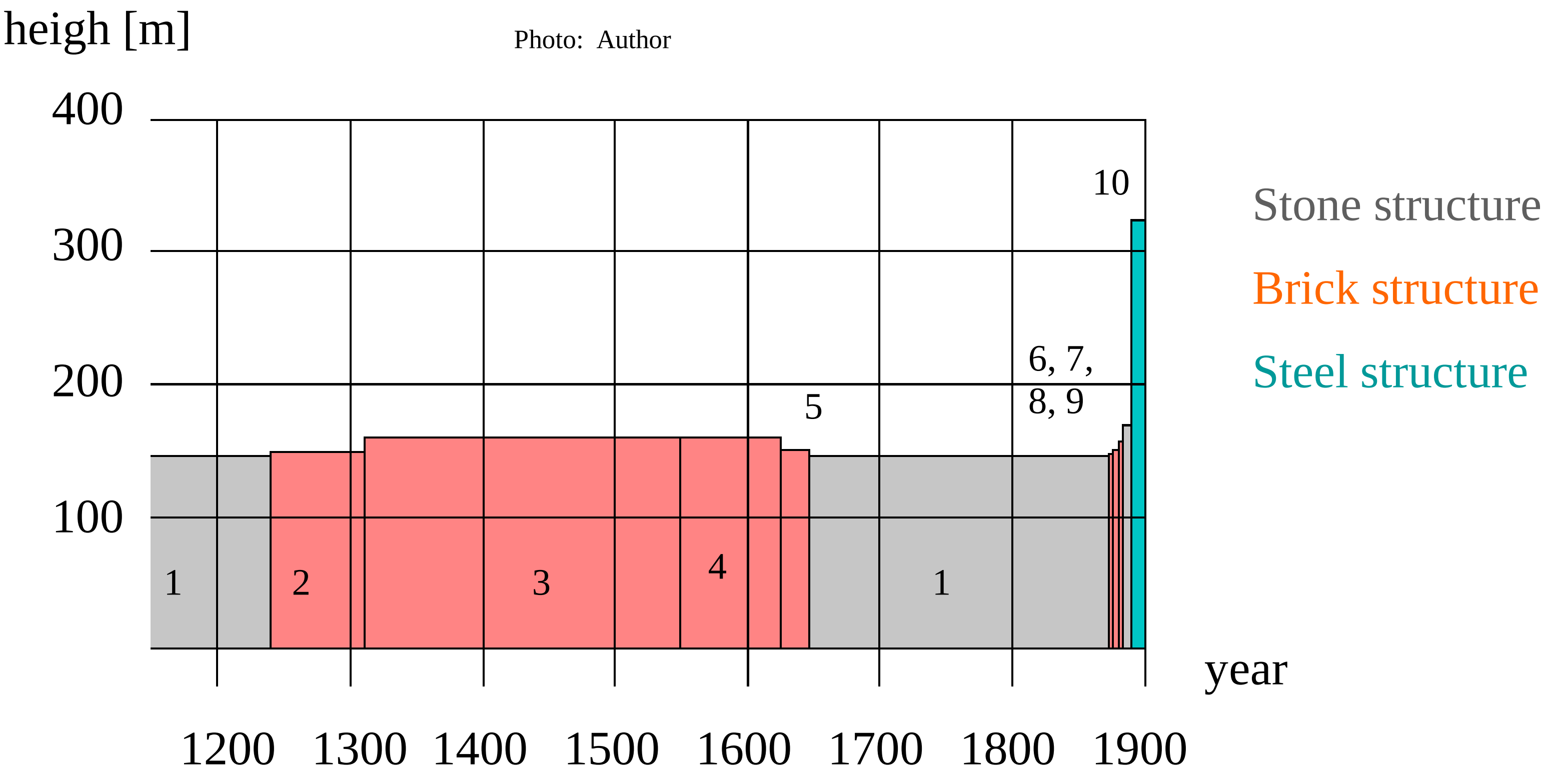
Photo: wikipedia

Photo: wikipedia

Before discovery of welding technology, each steel structure was erected as riveted structure.

Photo: krakow.come2europe.eu

# The highest structures for centuries



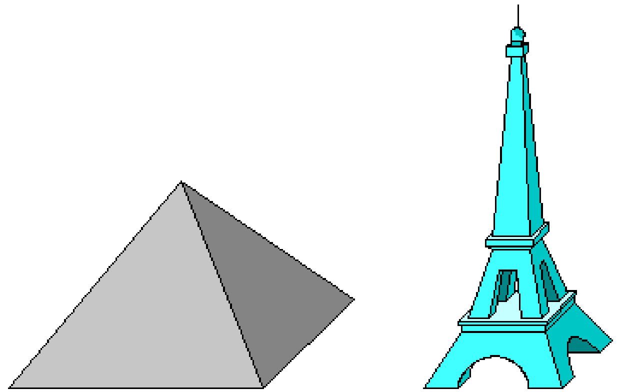

1. Cheops Pyramid 2. Old London Cathedral 3. Lincoln Cathedral 4. St Olaf's Church, Tallin 5. St Mary's Church, Stralsund 1. Cheops Pyramid 6. St Nicholas's Church, Hamburg 7. Rouen Cathedral 8. Cologne Cathedral 9. Washington Monument 10. Eiffel Tower

# Cheops Pyramid and Eiffel Tower

Structure:

base 230x230 m

height 146 m



Structure:

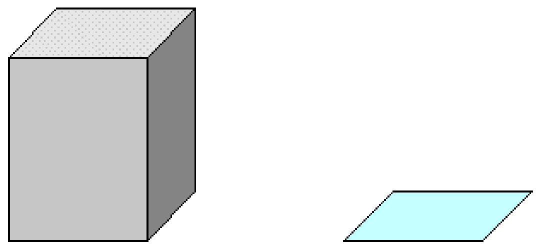
base 125x125 m

height 324 m

Volume of material:

base 125x125 m

height 165 m



Volume of material:

base 125x125 m

height 0,08 m (8 cm!)

Photo: Author

Welding technology (gas):

1836, Great Britain - Edmund Davy discovered acetylene;

1862, Germany - Frederick Wöhler discovered calcium carbide, called carbide;
carbide + water → acetylene (very cheap method of production)

1883, Poland - Karol Olszewski and Zygmunt Wróblewski produced the first in world measurable quantity of liquid oxygen (LOX);

1894, France - Henryk Maisson invited method of mass production of carbide

1901, France - Edmond Fouche and Charles Picard construct LOX-acetylene welding torch.

Photo: anthonycarts.com

Photo: victortechnologies.com

Welding technology (arc, termite):

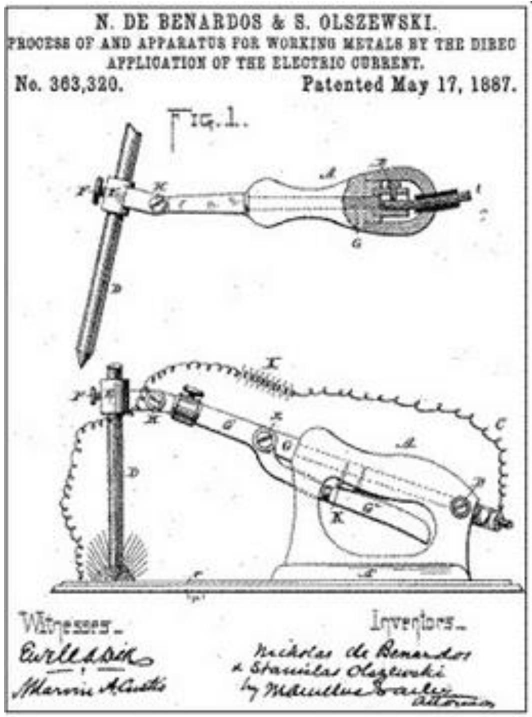



Photo: wikipedia

1882, Russia - Stanisław Olszewski and Mikołaj Benardos patented arc welding technology.

1894, Germany - Hans Goldschmidt invented termite welding technology.

Photo: pl.all.biz

More information → lec. #16

Beginning of XX century to today - modern steel structures, riveted, bolted and welded.

Photo: wikipedia

Photo: wikipedia

Photo: skyscrapercity.com

# Main construction materials

Concrete ~35% structures

Metals ~35% structures

Masonry ~25% structures

Timber ~5% structures

Metals as construction materials:

Steel ~95% metal structures

Aluminum ~5% metal structures

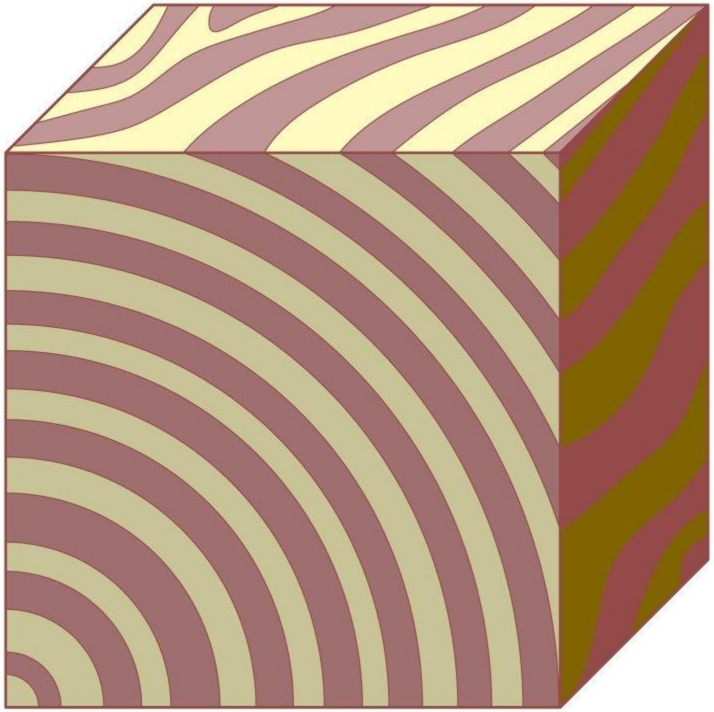


Photo: Author

Photo: sadolin.pl

Timber

- Biological

  humidity is important for strength characteristics

- Heterogenous

  tensile strength is different than compression strength

- Anisotropic

  strength characteristics depend on the directions

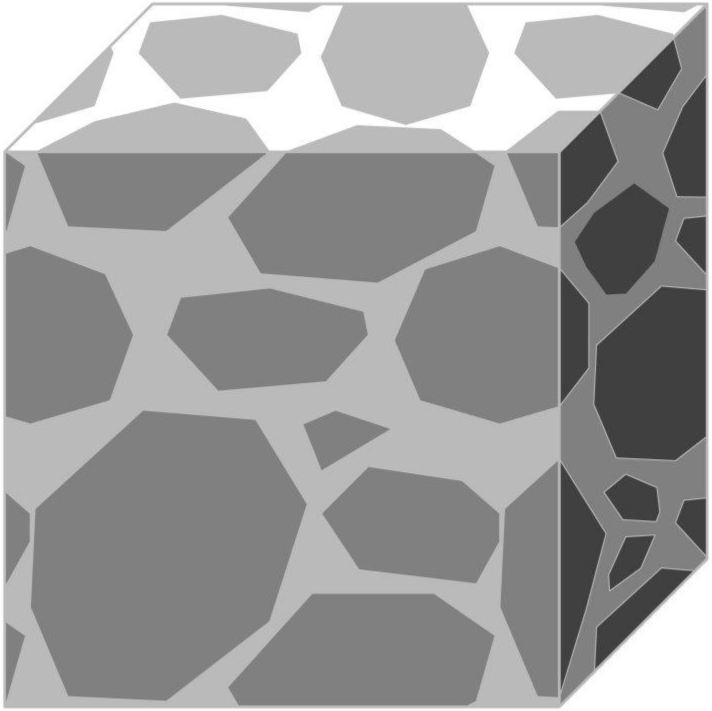


Photo: Author

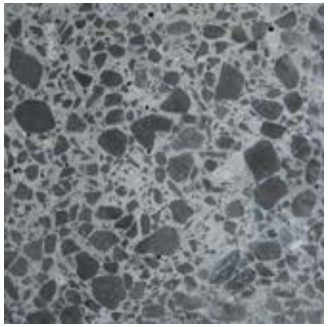


Photo: swiatbetonu.pl

Concrete

- Heterogenous

  tensile strength is different than compression strength

- Isotropic

  strength characteristics are the same in each directions

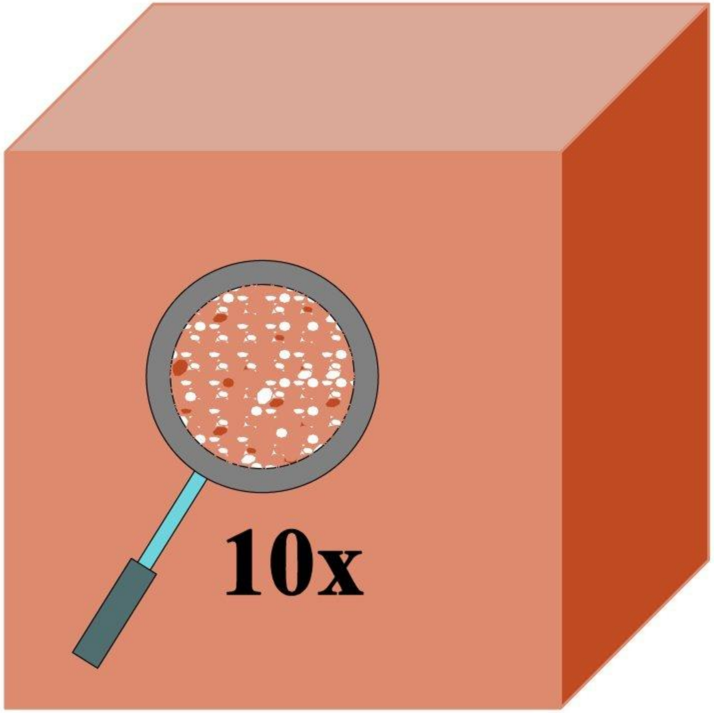



Photo: Author

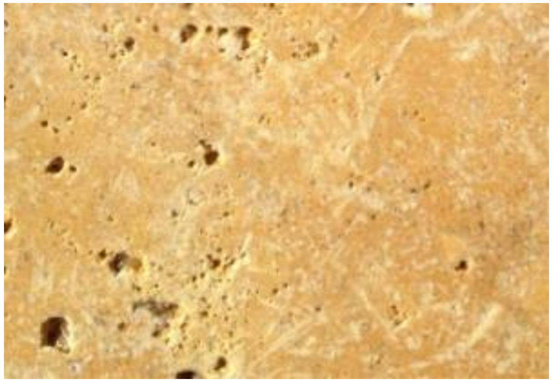


Photo: duroshine.com

Ceramics

- Heterogenous

  tensile strength is different than compression strength

- Isotropic

  strength characteristics are the same in each directions

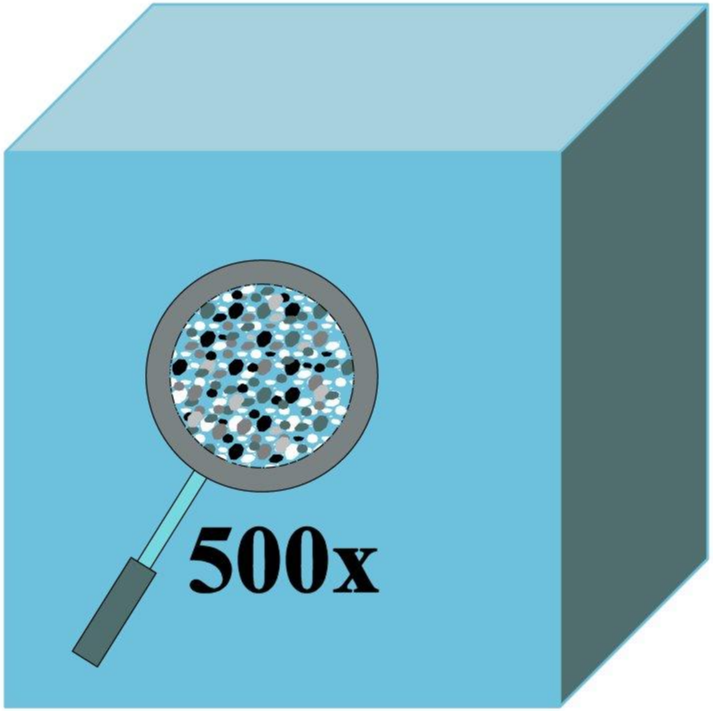
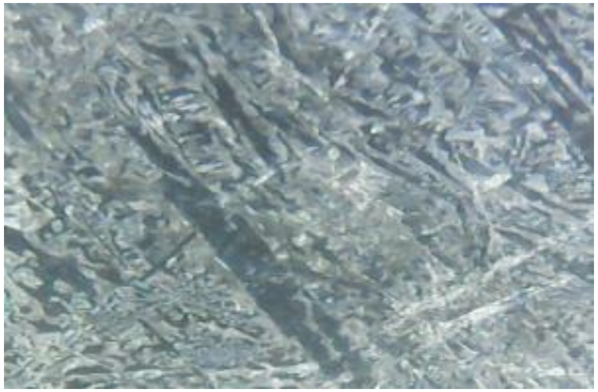



Photo: Author



Metals

- Homogenous

  tensile strength is the same as compression strength; $f_y$

- Isotropic

  strength characteristics are the same in each directions

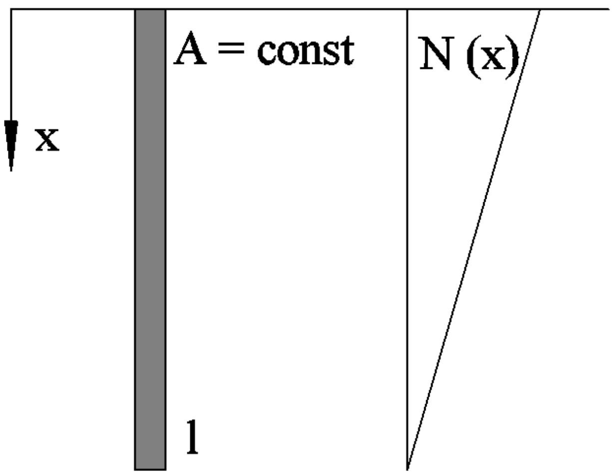
Metals and other building materials

| Material | Strength $f_y$ [MPa] | Dead weight d [kN/m$^3$] | Lightness $\kappa = d / f_y$ [0,001/m] |
|---|---|---|---|
| Steel for tension components | 1 450 - 2 300 * | 78,5 | 0,03 - 0,05 |
| High-strength steel | 450 - 700 | 78,5 | 0,11 - 0,17 |
| "Normal" steel | 235 - 355 | 78,5 | 0,22 - 0,33 |
| Aluminum | 110 - 280 | 27,0 | 0,10 - 0,25 |
| Concrete | 30 - 50 ** | 25,0 | 0,50 - 0,83 |
| Ceramics | 5 - 20 ** | 20,0 | 1,00 - 4,00 |
| Wood | 5 - 10 | 7,0 | 0,70 - 1,40 |

* $f_u$ **resistance for compression

Vertical cantilever - axial force from dead weight

Photo: Author




$$N_{max}\,(x) = N\,(0) = A\,l\,d$$

$$\sigma_{max} = N_{max} / A = l\,d$$

$$\sigma_{max} \leq f_y$$

$$l = \max \leftrightarrow \sigma_{max} = f_y$$

$$l_{max}\,d = f_y$$

$$l_{max} = f_y / d = 1 / \kappa$$

| | $l_{max}$ [m] |
|---|---|
| Steel for tension components * | 18 500 - 29 300 |
| High-strength steel | 5 900 - 9 100 |
| "Normal" steel | 3 000 - 4 500 |
| Aluminum | 4 000 - 10 000 |
| Concrete ** | 1 200 - 2 000 |
| Ceramics ** | 250 - 1 000 |
| Wood | 700 - 1 400 |

* $f_u$ **resistance for compression

<table>
<tr><th></th><th>☺</th><th>☹</th></tr>
<tr><td>Steel</td><td rowspan="2">◆ High tensile strength<br>◆ High degree of prefabrication<br>◆ Easy to enhance facilities<br>◆ Possibility of demountable structures<br>◆ Full recycling of alloy used for building structures<br>◆ Lightweight</td><td>◆ Susceptibility to corrosion<br>◆ No fire resistance</td></tr>
<tr><td>Aluminum</td><td>◆ High cost of material<br>◆ No fire resistance<br>◆ Susceptibility to thermal destruction<br>◆ Low fatigue strength</td></tr>
</table>

Examples of steel and aluminum structures

Photo: setrometalgroup.com

„Light" frame hall, hot-rolled cross-sections, (I^st step of studies)

„Light" frame hall, welded cross-sections, (I^st step of studies)

Photo: traskostal.pl

Truss roof girder, (I^st step of studies)

Photo: rolstal.com

Industrial supporting structure,
(I^st step of studies)

Photo: monta.pl

# Steel skeleton, residential building, (I$^{st}$ step of studies)

Photo: stalart.com.pl

# Steel skeleton, office building, (I$^{st}$ step of studies)

Photo: hale.info

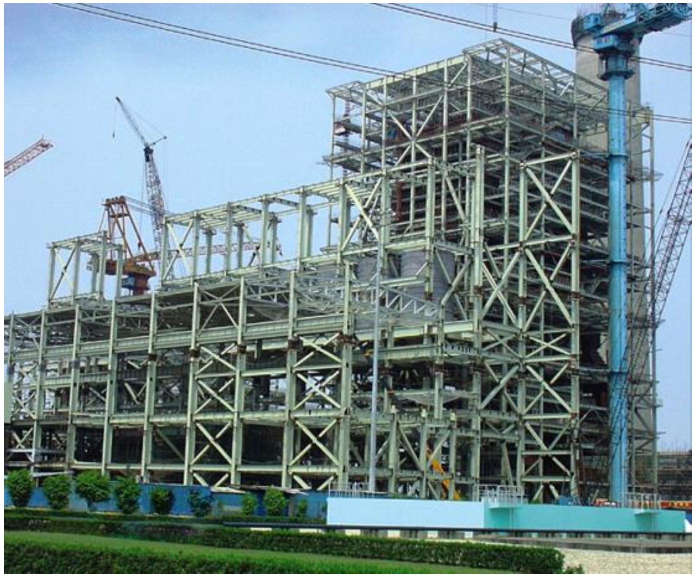


Photo: atechleader.com

# Steel skeleton, industrial building, (I$^{st}$ step of studies)

„Heavy” frame hall with crane, (II$^{nd}$ step of studies)

Photo: stabud.eu

Crane supporting structure, (II$^{nd}$ step of studies)


Photo: zksgrzelak.eu

Steel skeleton, skyscraper, (II$^{nd}$ step of studies)

Photo: skyscrapercity.com

Photo: wikipedia

Silo, (II$^{nd}$ step of studies)

Photo: gpd24.pl

Chimney, (II$^{nd}$ step of studies)

Photo: carrasquilloassociates.com

Pipeline, (II$^{nd}$ step of studies)

Photo: iniekt-system.pl

Spherical tank, (II$^{nd}$ step of studies)

Photo: wikipedia

Cylindrical tank, (II$^{nd}$ step of studies)

Photo: kbpomorze.pl

Watertower, (II$^{nd}$ step of studies)

Photo: wikipedia

Electro – energetic tower,
(II$^{nd}$ step of studies)

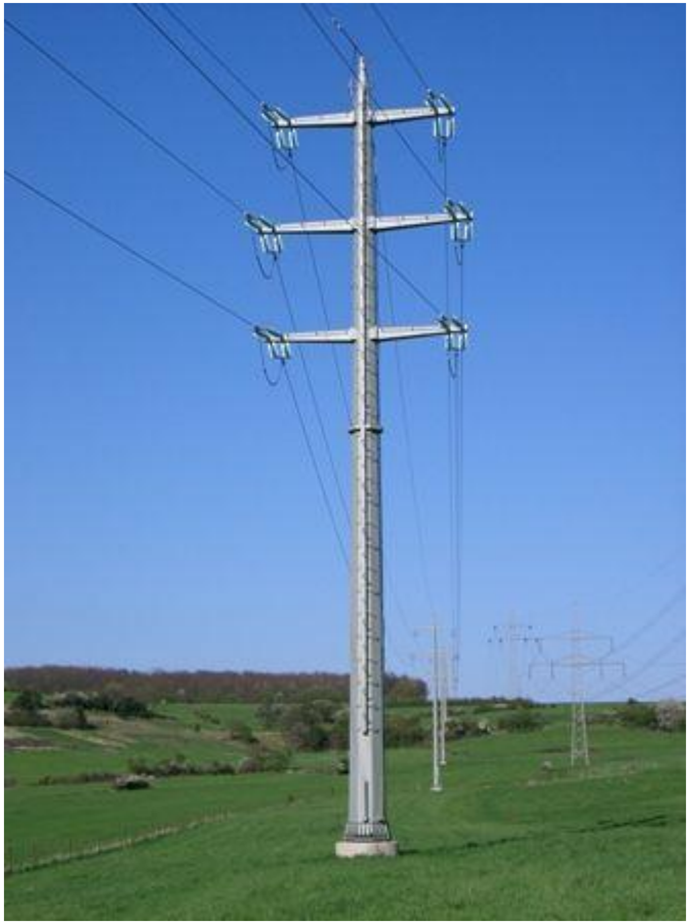


Photo: inzynieria.com

Photo: wikipedia

Mast, tower, (II$^{nd}$ step of studies)

Spatial truss, (IInd step of studies)

Photo: xzlf.en.hisupplier.com

Ropeway, (IInd step of studies)

Photo: wikipedia

Suspension roof, (IInd step of studies)

Photo: wikipedia

## Bridge, ( I$^{st}$ and II$^{nd}$ step of stuies)

Photo: wikipedia

## Windmill tower

Photo: wikipedia

## Offshore platform

Photo: globalsources.com

Aluminum: greenhouse, Kraków Botanic Garden

Photo: wikipedia

Mast, tower

Photo: e-signals.pl

Movable temporary structure

Photo: .wamat.com.pl

## **Sources of iron**

Meteorites

Iron ore

Polymetalic nodules

Core of Earth

# Meteorites: stone-iron or iron

Photo: ptmet.org.pl

Iron ore: magnetite

($FeO \cdot Fe_2O_3$) + impurities

40% - 70% Fe

Photo: wikipedia

Iron ore: hematite

($Fe_2O_3$) + impurities

30% - 70% Fe

Photo: geopasja.p

Iron ore: siderite

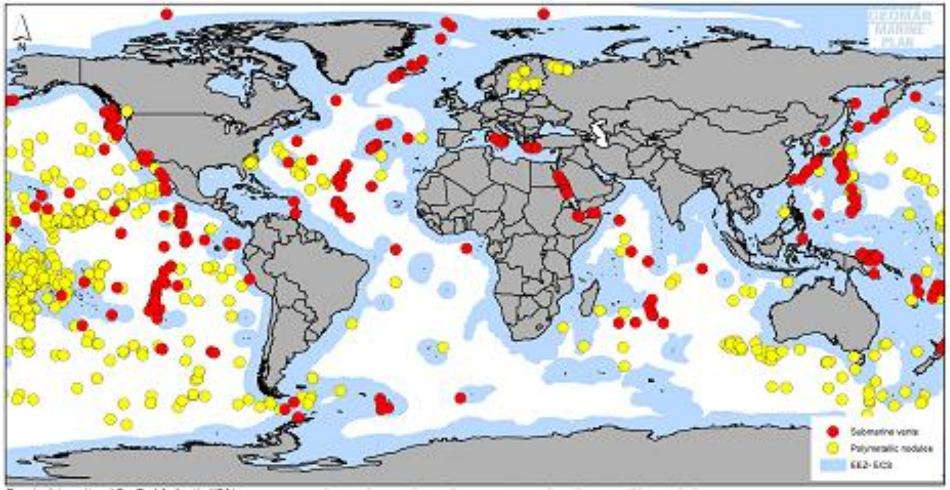
($FeCO_3$) + carbonates
30% - 50% Fe

Photo: wikipedia

Iron ore: limonite (bog ore)

($FeO(OH){\cdot}nH_2O$) + loam
25% - 40% Fe

Photo: wikipedia




Fuente: International SeaBed Authority (ISA)

**Location submarine vents and polymetallic nodules**

Photo: marineplan.es

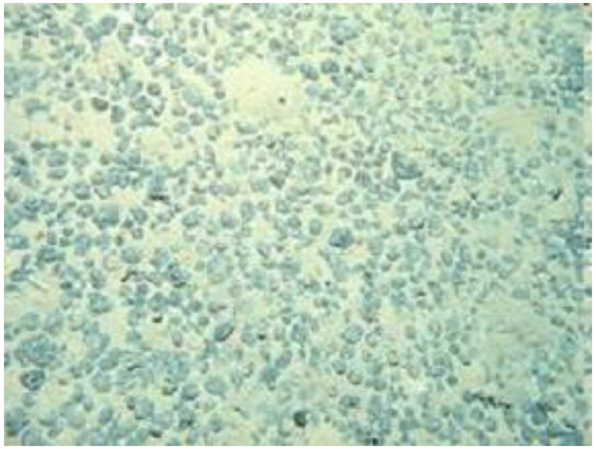


Photo: wikipedia

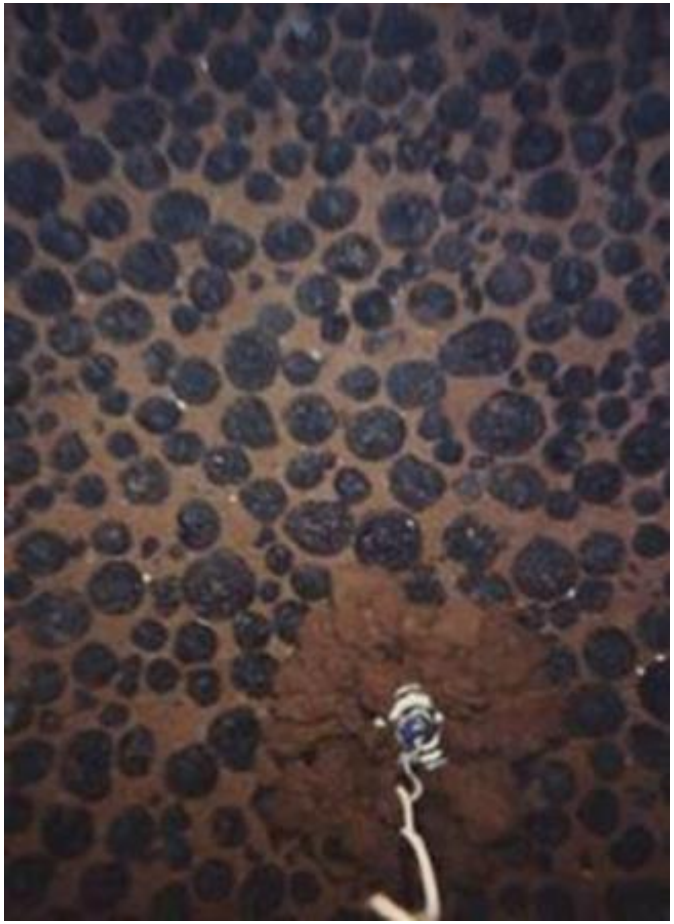


Photo: oldisa.mobilemedia.com.jm

# Polymetalic nodules

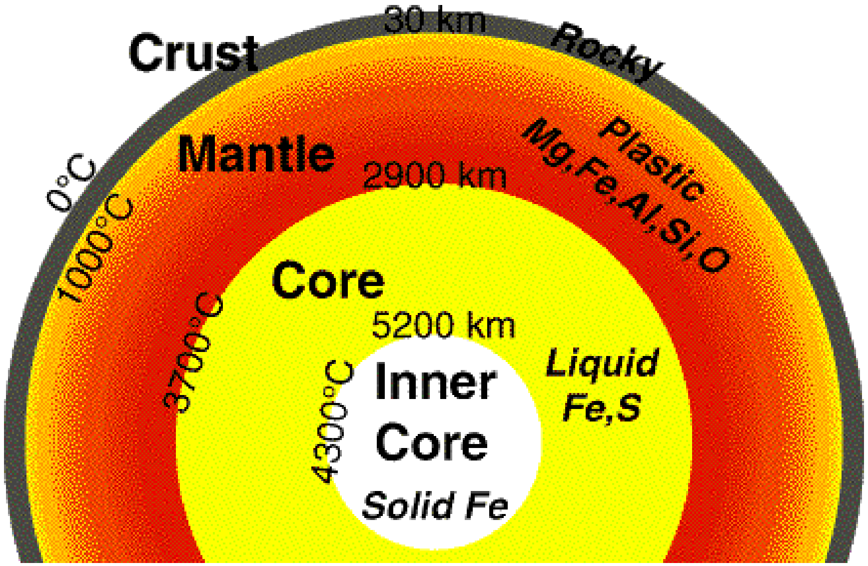



Photo: crack.seismo.unr.edu

Core of Earth

# Furnace process


Photo: wikipedia

# First step: mineral processing

Grinding of iron ore and mechanical, chemical or thermal removal part of impurities.

Photo: wikipedia

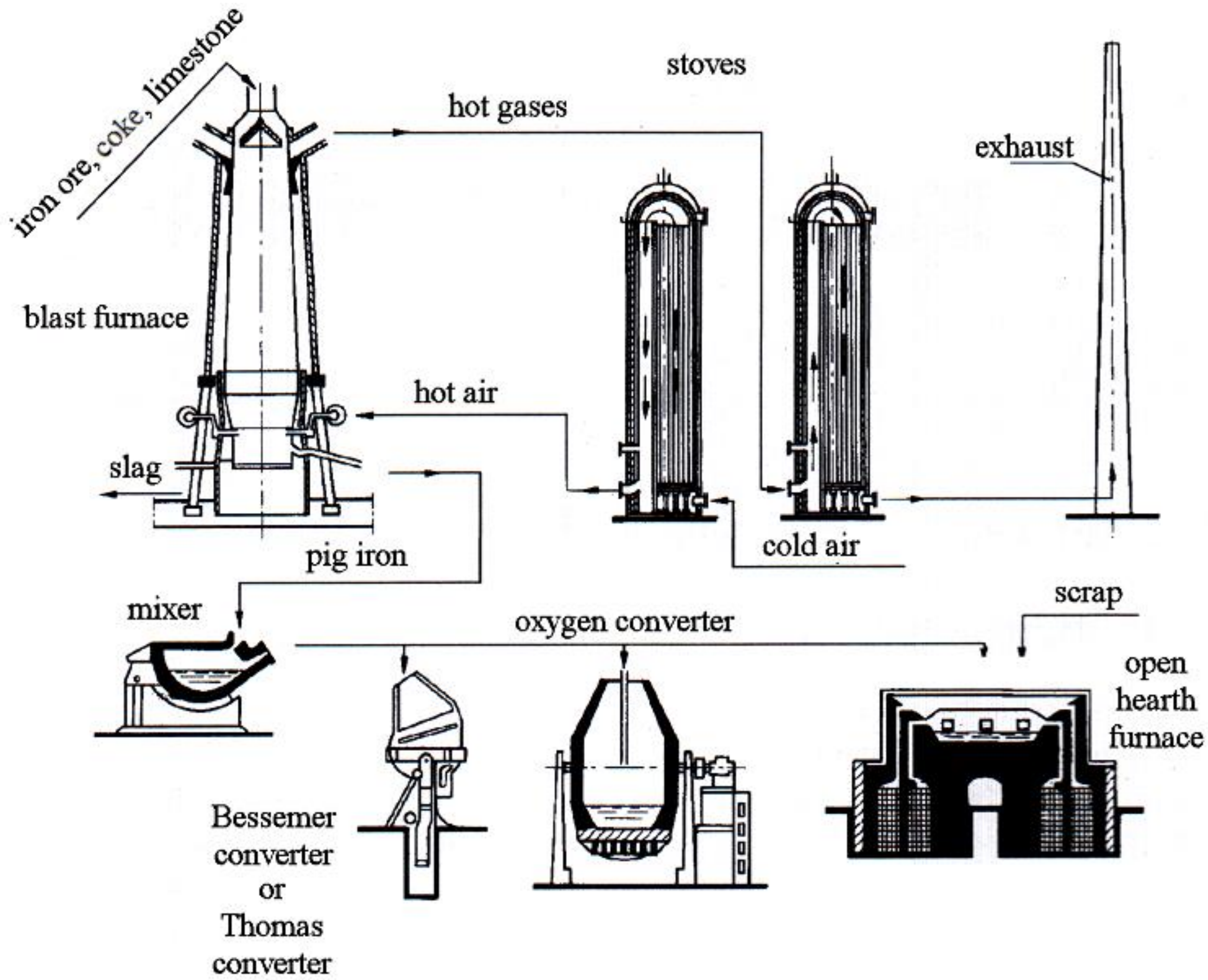



Photo: Łubiński M, Filipowicz A, Żółtowski W, "Konstrukcje metalowe", Arkady 2000

Feed materials:

Granulated iron ore - source of iron and oxygen;

Coke - source of carbon and heat;

Limestone - flux, in high temperature transforms to liquid and makes good environment for chemical reactions; eventually keeps impurities and ash → slag.

Photo: feeco.com

Photo: carbonotech.com

Photo: usedstonecrushers.com

# Blast furnace regions

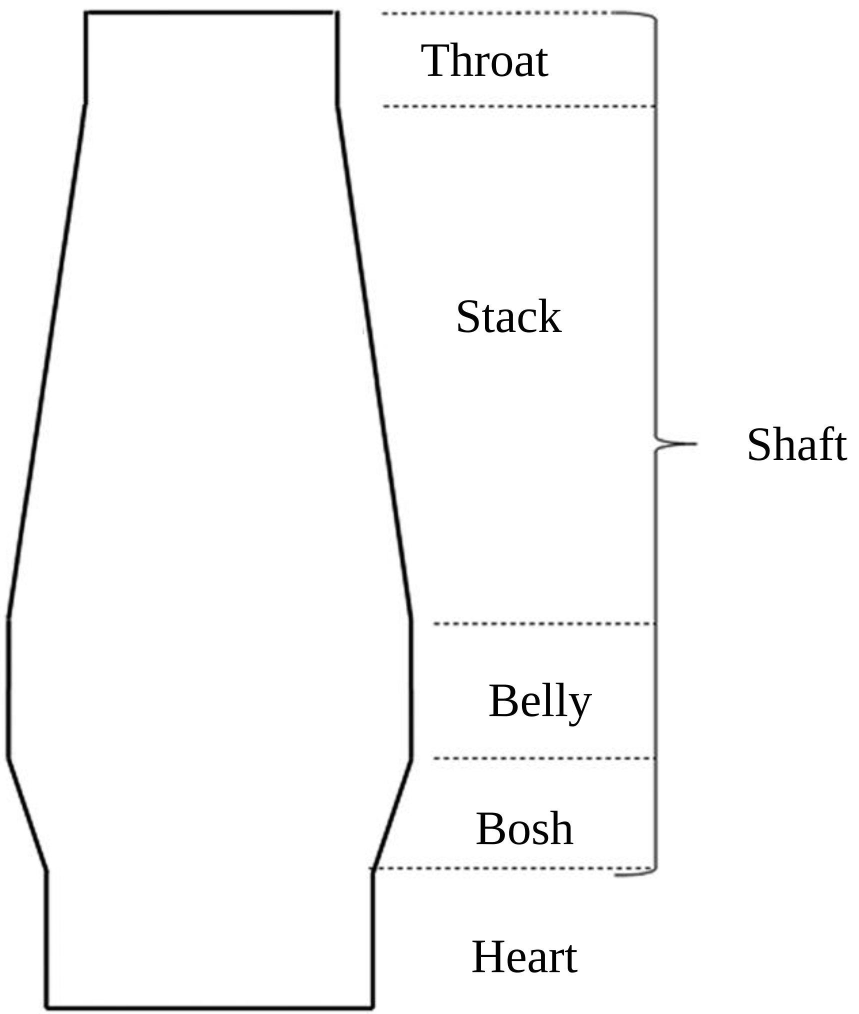



Photo: asmedigitalcollection.asme.org

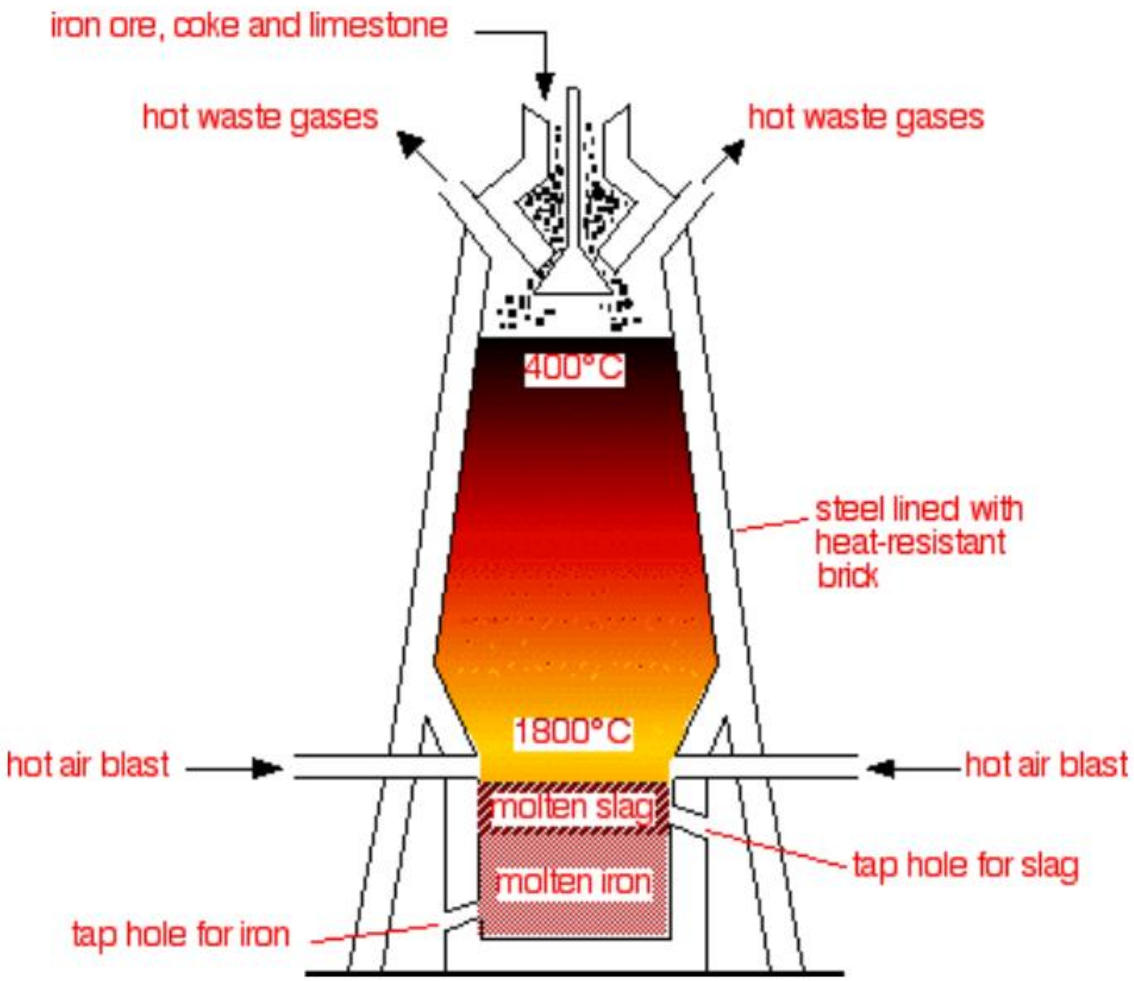


Photo: practicalmaintenance.net

Feed materials wander down

⇩

Heat and gases wander up

⇧

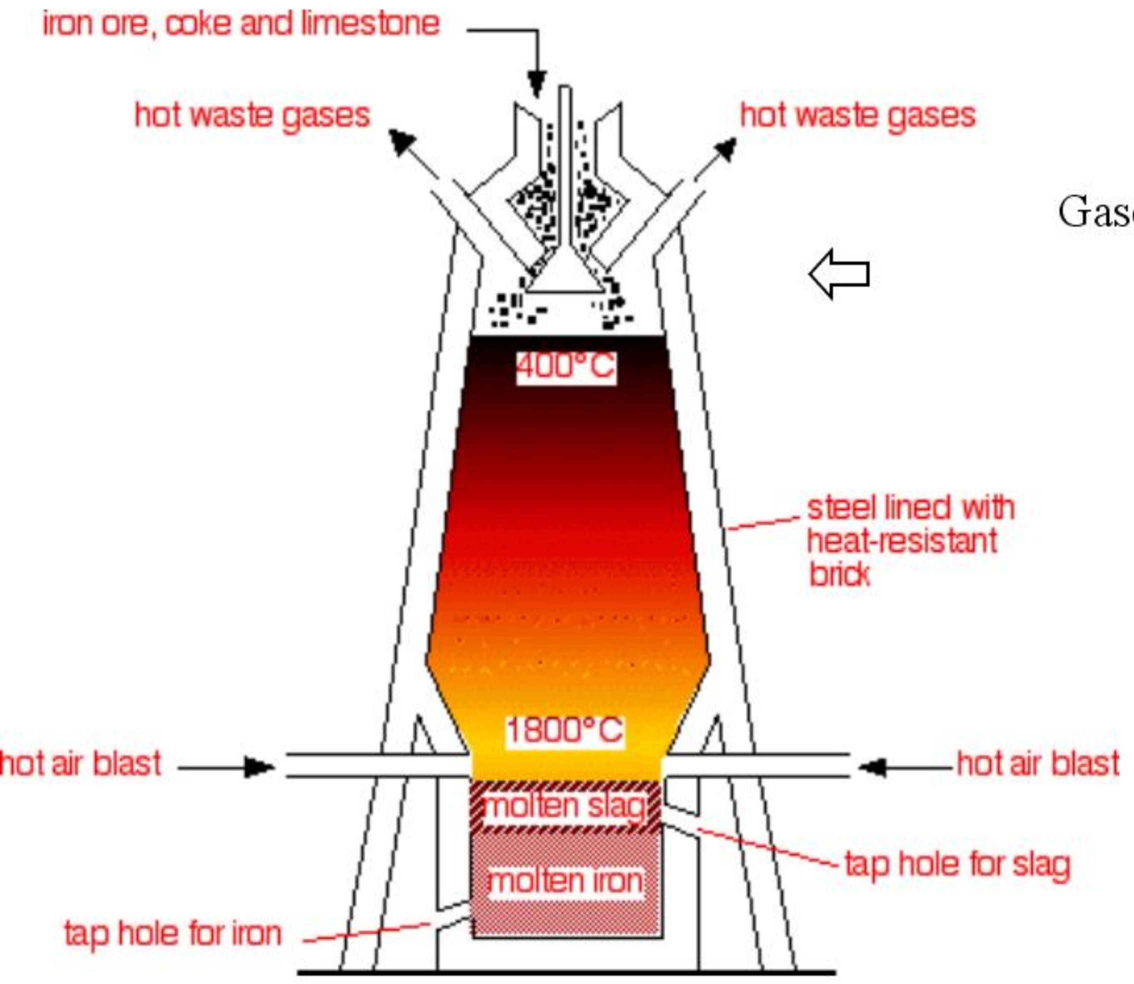



Photo: practicalmaintenance.net

Throat:

Gases, heat ⇧ Feed materials ⇩

Top part of stack:

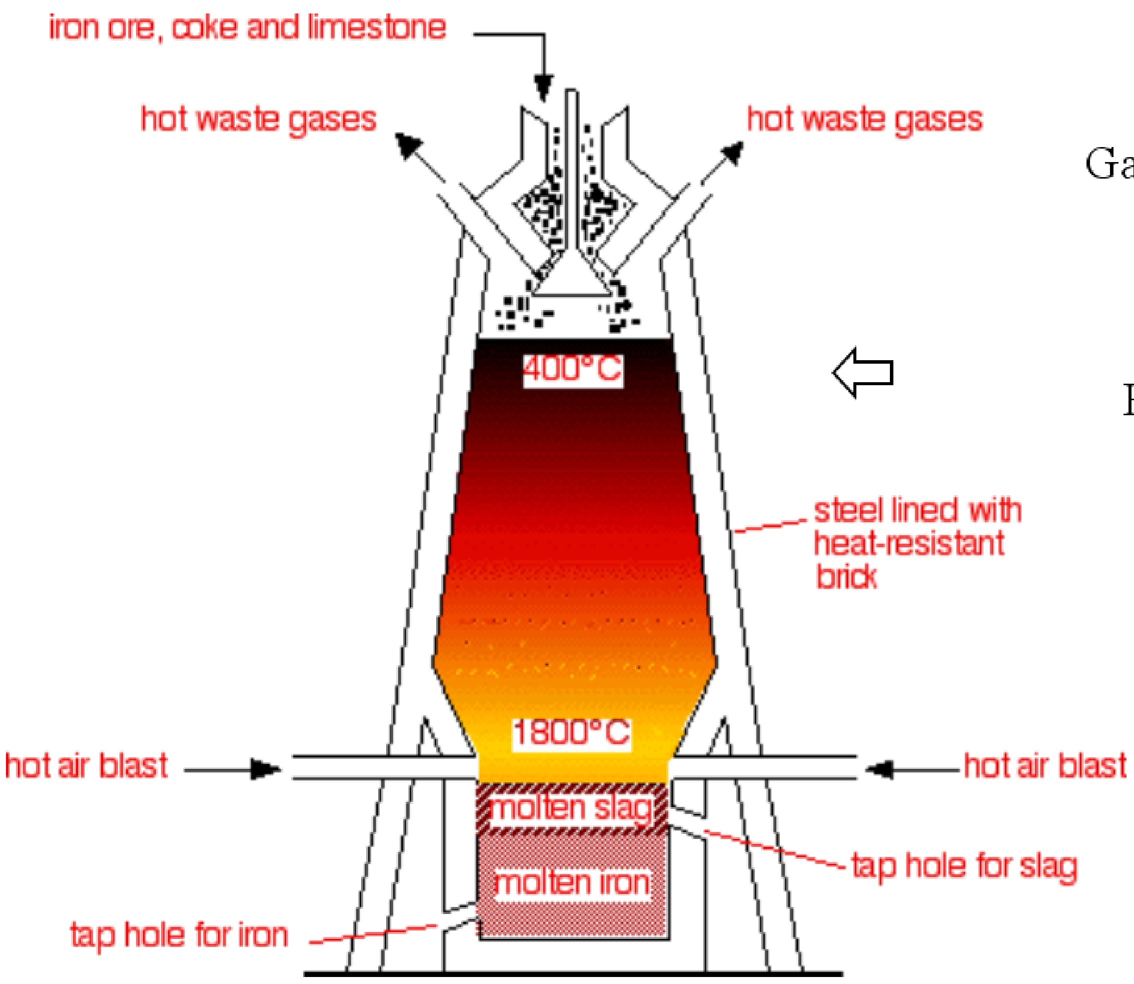



Photo: practicalmaintenance.net

Gases, heat ⇧ Feed materials ⇩

Moisture evaporated

Heat, $CO_2$ ⇧ Feed materials ⇩

Central and bottom part of stack:

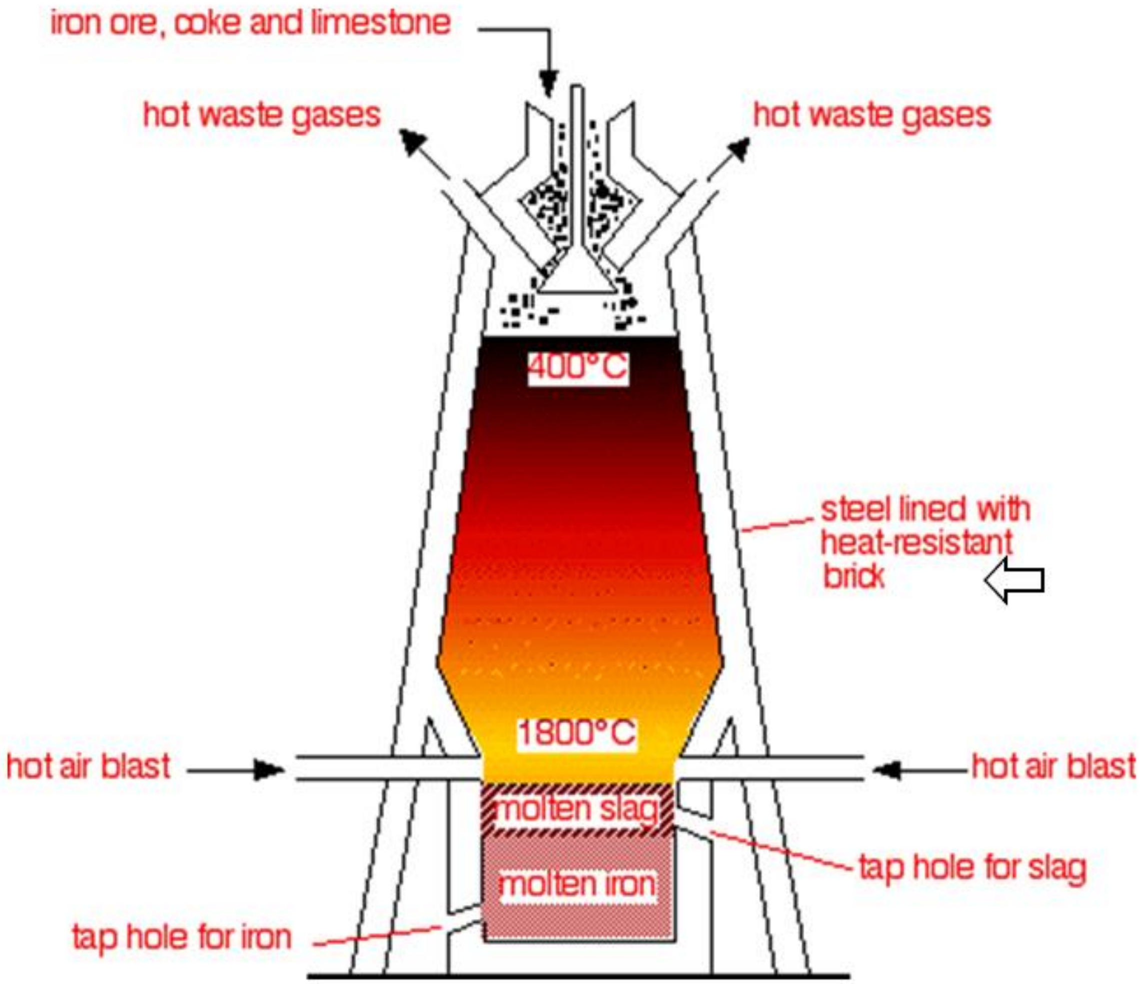



Photo: practicalmaintenance.net

Heat, $CO_2$ ⇧ Feed materials ⇩

$$3\,Fe_2O_3 + CO = 2\,Fe_3O_4 + CO_2$$

$$Fe_3O_4 + CO = 3FeO + CO_2$$

Heat, CO ⇧ FeO, C, limestone, pollutions ⇩

Belly:

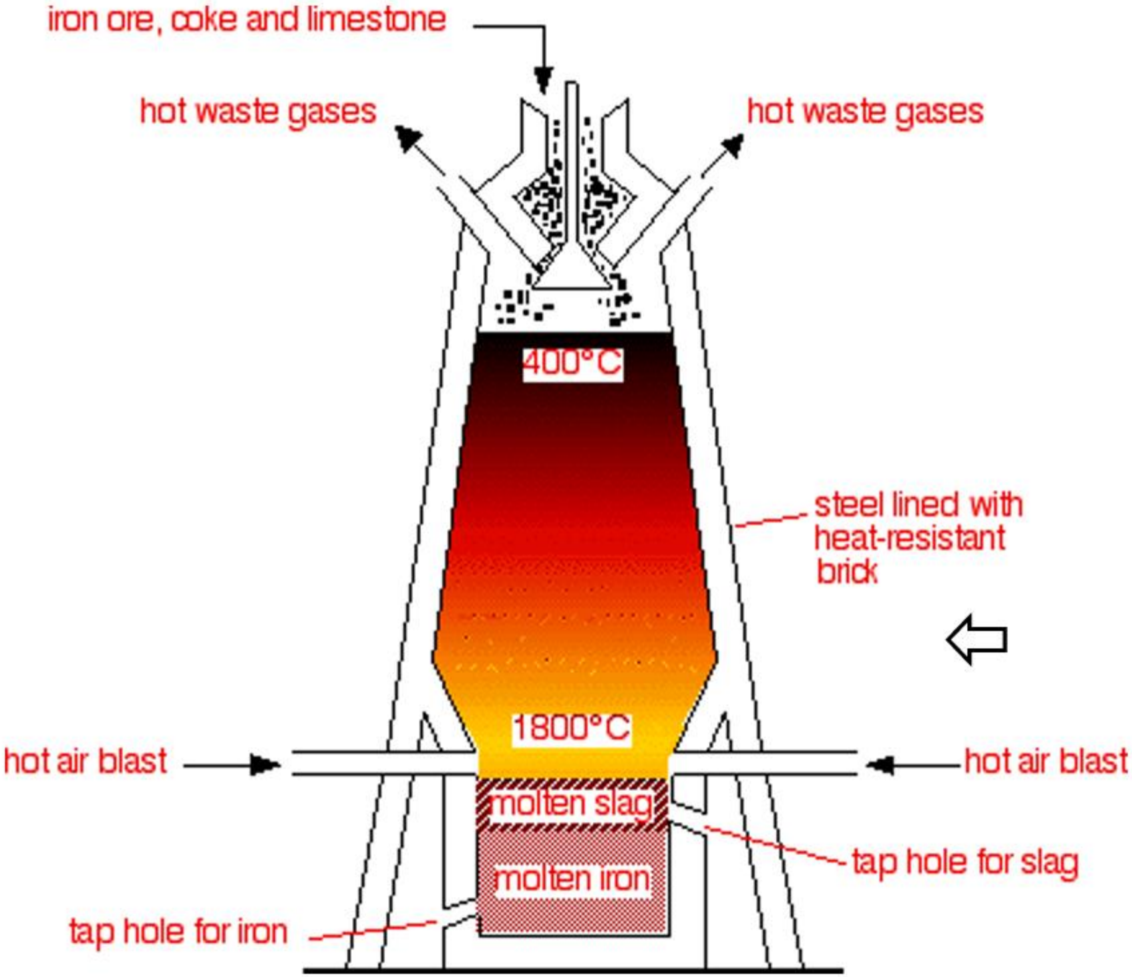



Photo: practicalmaintenance.net

Heat, CO ⇧ FeO, C, limestone, pollutions ⇩

$$CO_2 + C = 2CO$$

$$FeO + C = Fe + CO$$

$$3Fe + 2CO = Fe_3C + CO_2$$

$$FeO + CO = Fe + CO_2$$

$$CaCO_3 = CaO + CO_2$$

Heat, $CO_2$ ⇧ Fe, C, CaO, pollutions ⇩

Bosh:

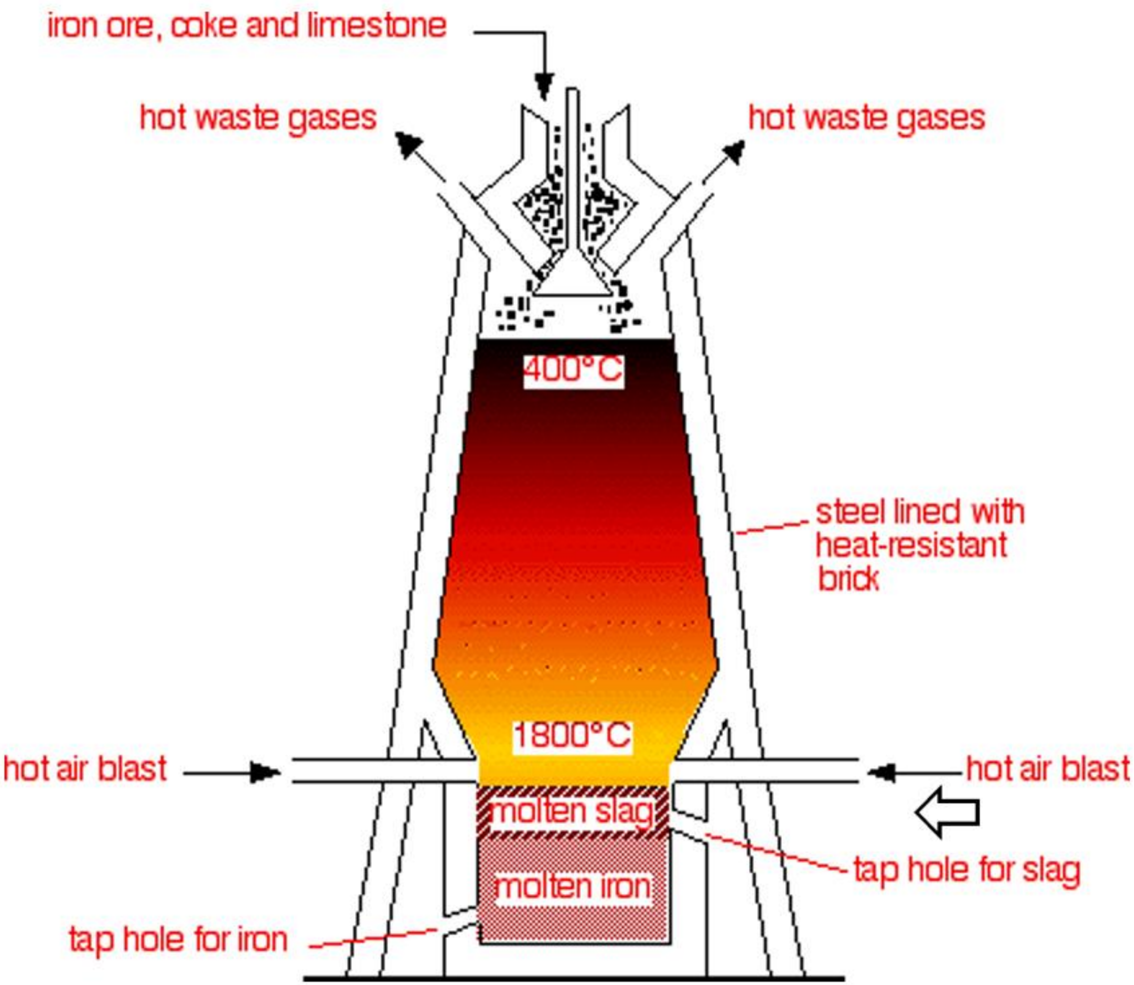



Photo: practicalmaintenance.net

Heat, $CO_2$ ⇧ Fe, C, CaO, pollutions ⇩

$$C + O_2 = CO_2 + heat$$

liquids ⇩ $O_2$ ⇦

Heart:

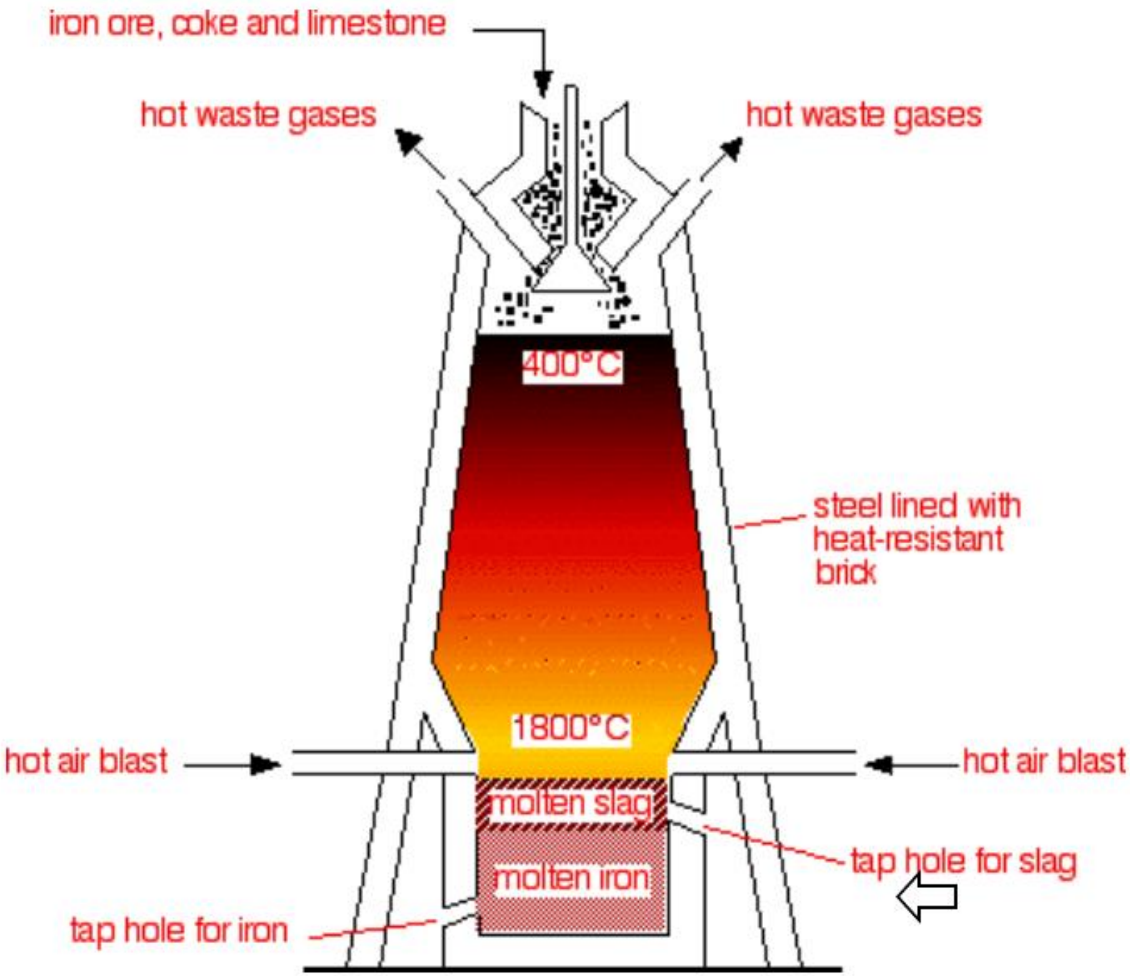



Photo: practicalmaintenance.net

liquids ⇩

Gravity separation of molten slag (light) and molten iron (heavy)

Products of blast furnace:

Pig iron

Slag

Gases

Photo: veooz.com

Photo: nowaautorska.com

Next step: pig iron travells to converters or open heart furnace

Hot oxygen or hot air removes rest part of impurities (refining).

Photo: uas.su

Photo: wikipedia

# Converters:

• Bessemer converter: inner covering sour, refining hot air, dedicated for iron ore with very small amount of phosphorus;

• Thomas converter: inner covering alkaline, refining hot air, dedicated for iron ore with big amount of phosphorus;

• Open heart furnace (Martin convertor): refining hot oxygen (no nitrogen), possibility of recycling large quantities of scrap metal;

Photo: freedfromtime.wordpress.com

Photo: slaskie.naszemiasto.pl

Photo: newsnow.gy/business

# Next step: steel ingot

Product of converters or owen. During solidification, impurities and gases are pushed to central top part of ingot. Top part can be cutted and removed after cooling. Thus it is removed next portion of impurities.

Photo: luzhenmin.diytrade.com

Photo: spaceflight.esa.int

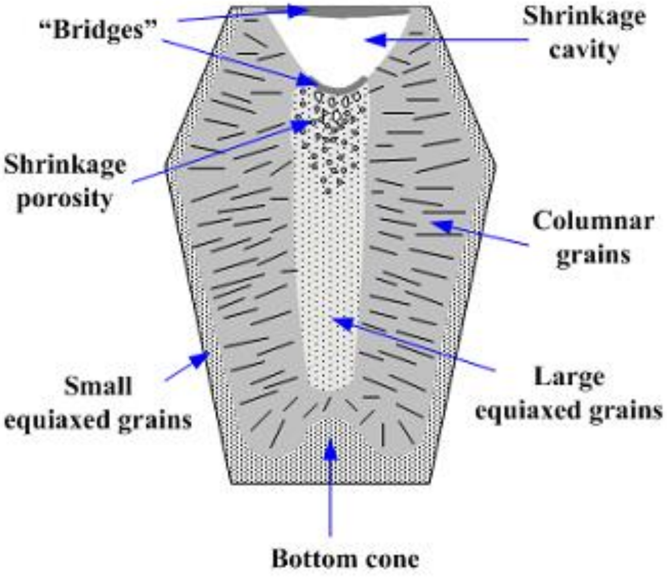



Photo: substech.com

Next step: electric arc furnace

Ingots are melted in electric arc furnace. Alloying elements are added to steel.

Alloying elements → Lec. #2

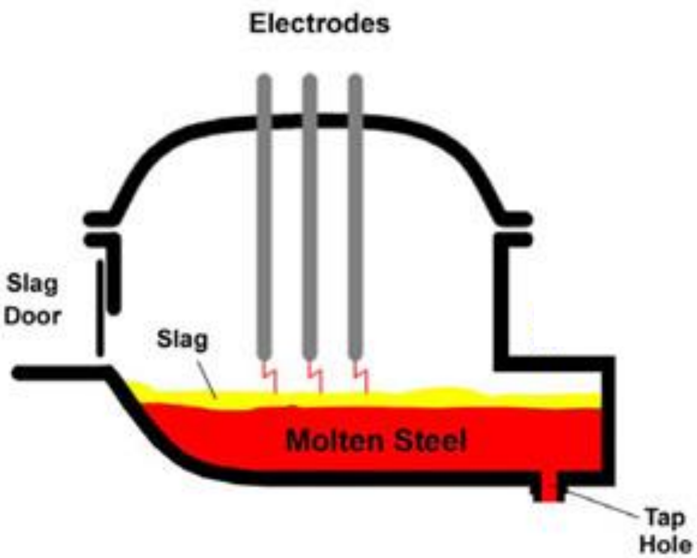



Photo: lenoxinst.com

Photo: wikipedia

Last step: from arc furnace, steel goes to roller mill.

Photo: wd-bearing.com

Photo: wd-bearing.com

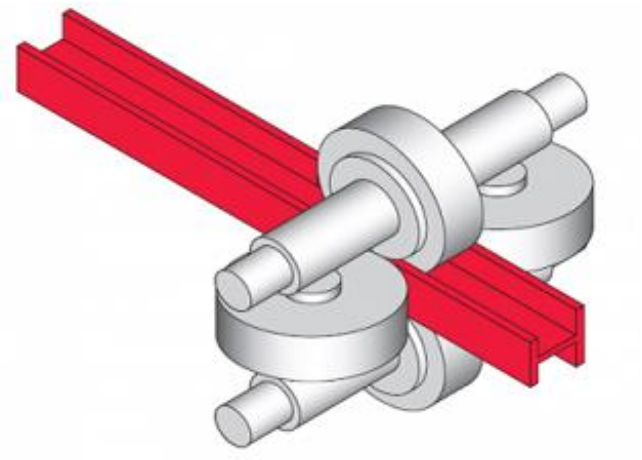


Photo: steelconstruction.info

**Steel products**

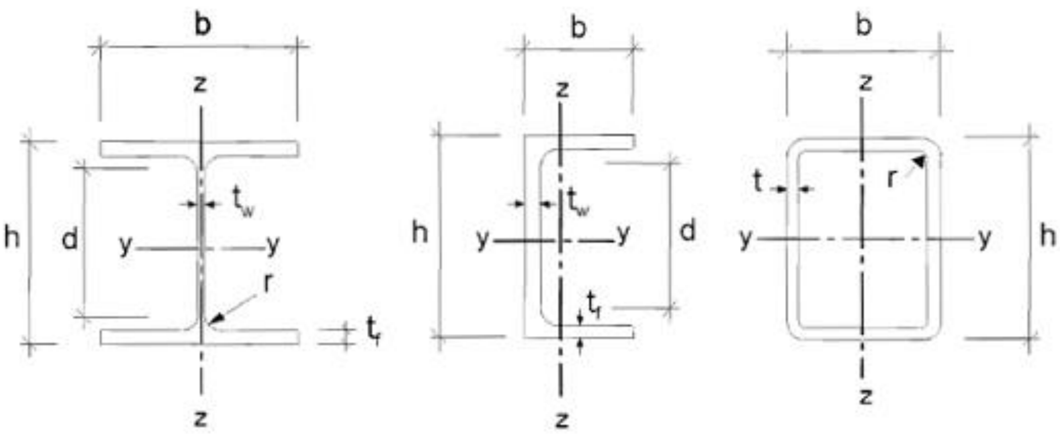
Hot-rolled

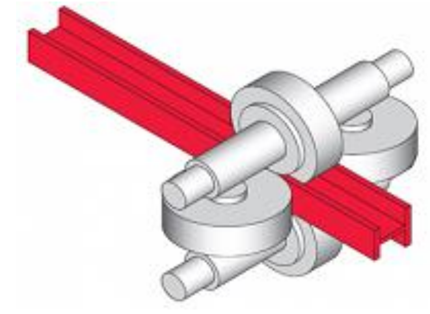
Cold-formed

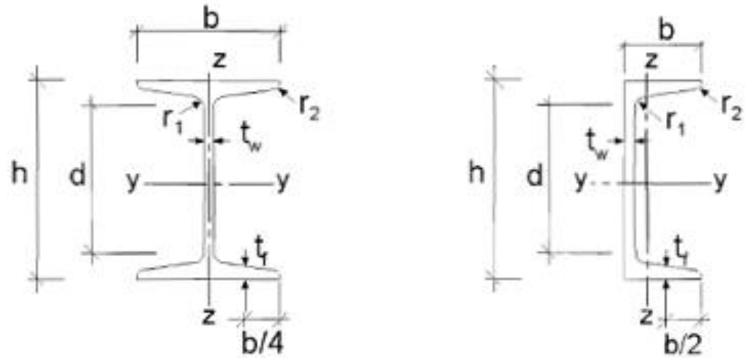
Welded

Other

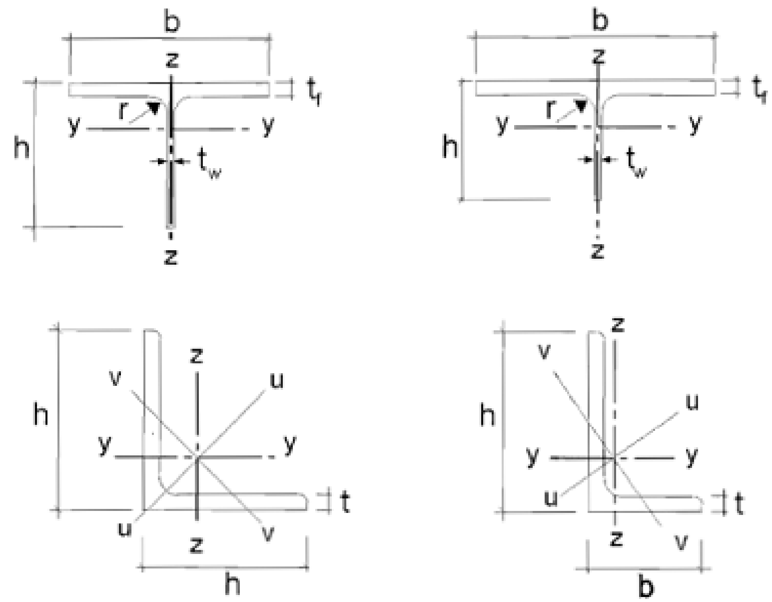
# Hot-rolled




EN 1993-1-1 fig 1.1



# I-beam

# (double-T)

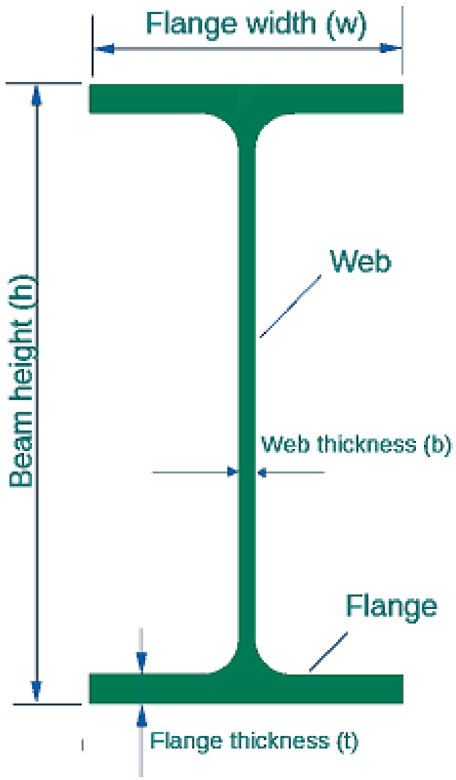



Photo: wikipedia

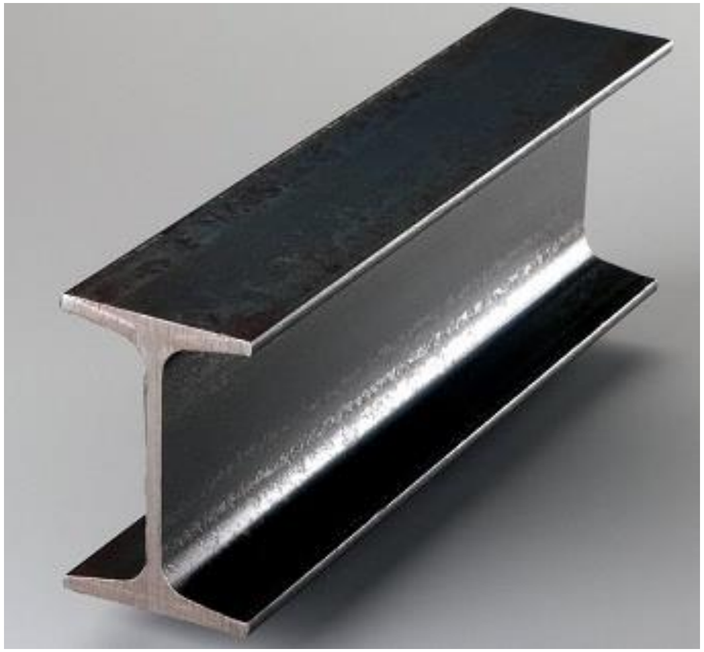


Photo: discountsteel.com

Photo: tradekorea.com

Information about differences between different types of I-beam is presented on Lab. #1.

# Channel section (C-section)

Photo: elezzsteel.com

Photo: mastersteel.com

Photo: edconsteel.com.au

# Angle section (L-section)

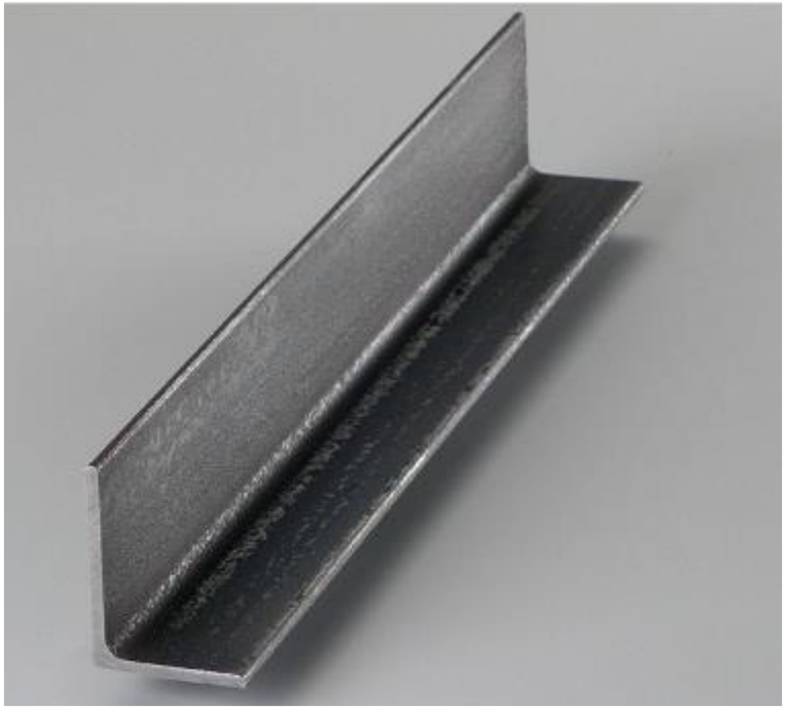
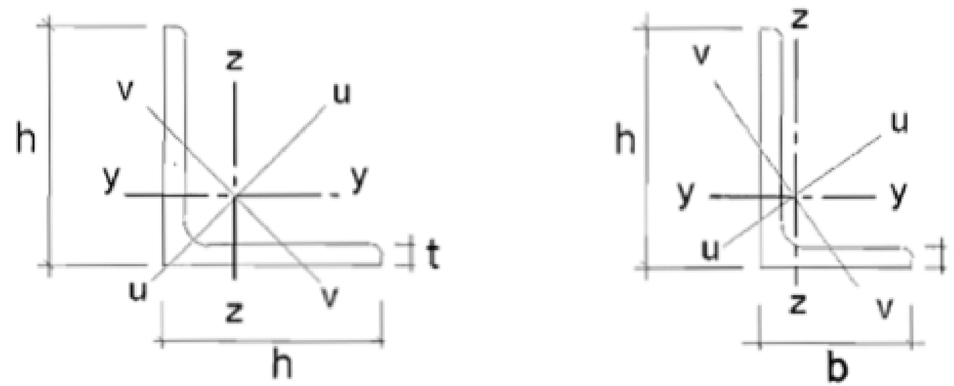


Photo: discountsteel.com

Photo: mastersteel.com




EN 1993-1-1 fig 1.1

Rectangular hollow section (RHS)

Circulat hollow section (CHS)

Photo: sunnysteel.com

Photo: pulhamsteels.co.uk

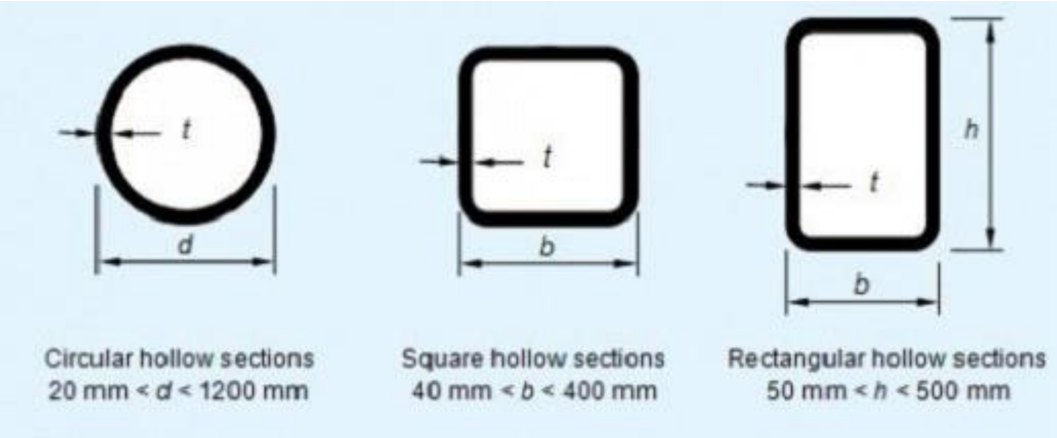



Photo: steelconstruction.info

## Plates and quasi-plates:

### Hoop iron (t = 1-5 mm; s = 20-85 mm)

Photo: steelstrap.en.ecplaza.net

### Plate in coils

Photo: threadedstainlesssteelpipe.com

### Flat steel (t = 6-55 mm; s = 20-150 mm)

Photo: corten.com

### Plate sheets

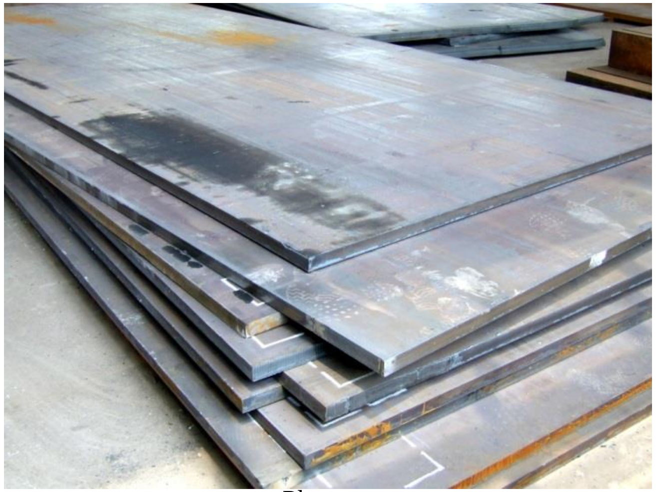


Photo: corten.com

Plate sheets:

Flat

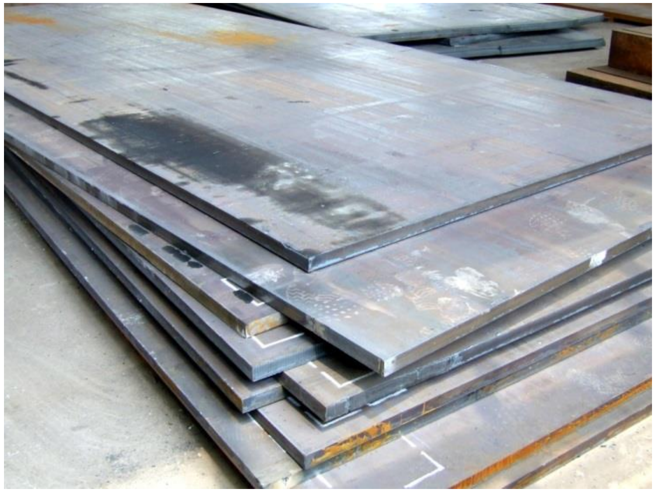


Photo: corten.com

Riffled

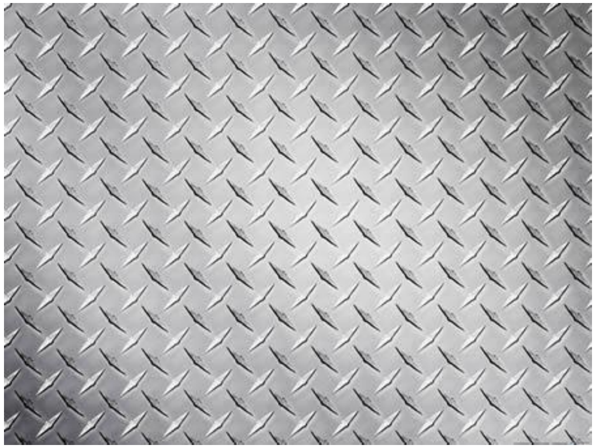


Photo: checker-plate.com

Flat plate sheets:

• cut from the coils;

• rolled in one direction;

• rolled in two directions (universal plate);

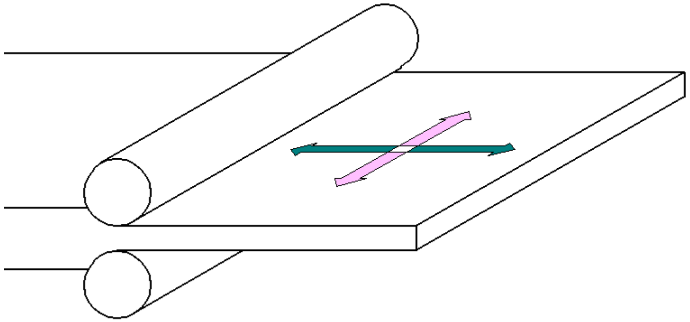


Photo: Author

# Cold formed

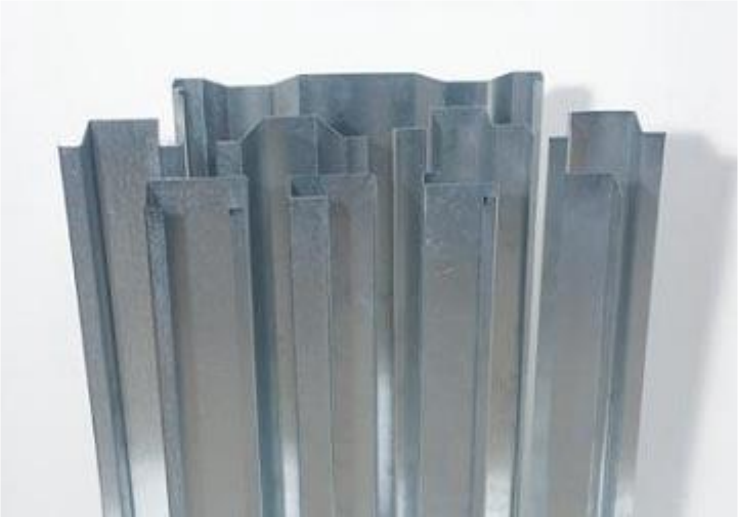


Photo: dachyb2b.pl

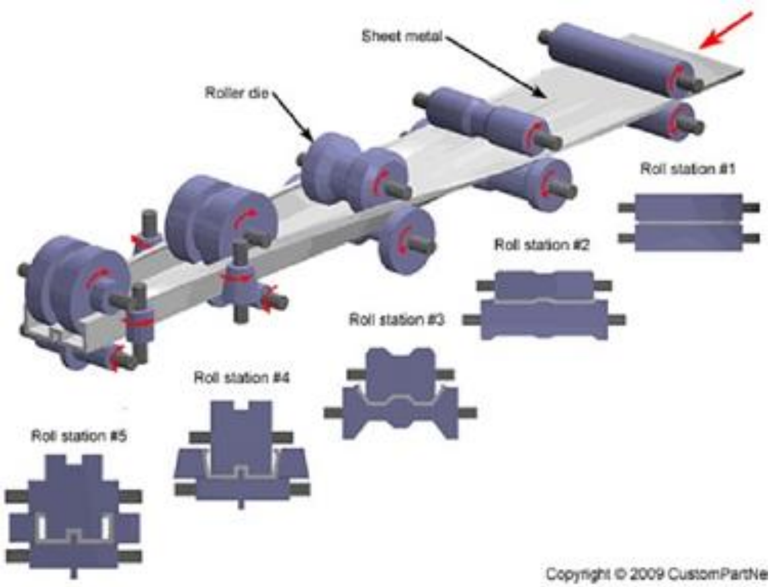



Photo: cnc.info.pl

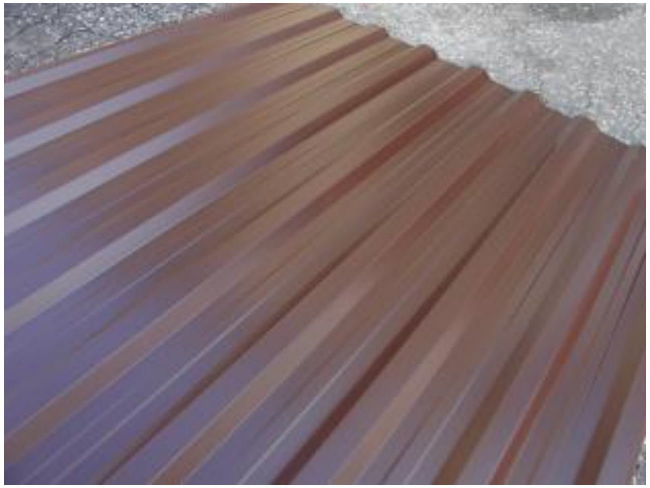


Photo: amarodachy.pl

Thin-walled structures

Photo: gramet-stal.pl

# Welded

Photo: steelconstruction.info

Photo: britannica.com

# Plate girders (welded I-beams)

Photo: savvats.com.ua

Photo: cedricbodeengineering.com

Photo: steelconstruction.info

# Plate girders with corrugated web

Photo: hxssvic.en.ec21.com

Photo: hera.org.nz

Photo: builtconstructions.in

# Castellated / cellular beams

Photo: steelconstruction.info

Photo: gunungsteel.com


Photo: steelconstruction.info

# Other

## bolt, pin, rivet, nut, washer, rope...


Photo: ventia.pl


Photo: rivetsonline.com


Photo: ferrodo-poznan.com.pl


Photo: rofix.pl


Photo: robotmesh.com

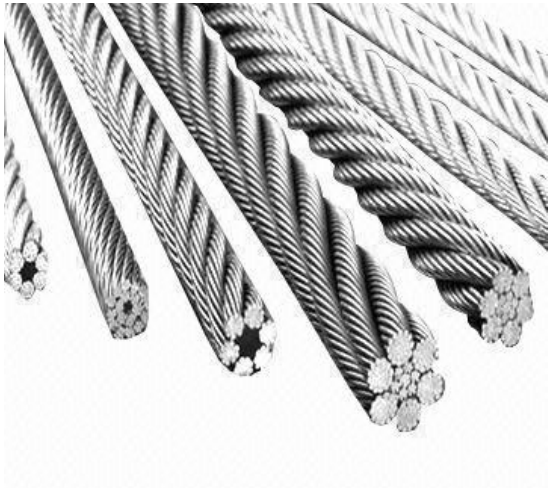


Photo: globalsources.com

# Internal structure of steel

Allotropy - existence of different form of chemical element, of different chemical or mechanical parameters. For example: carbon - graphite, diamond.

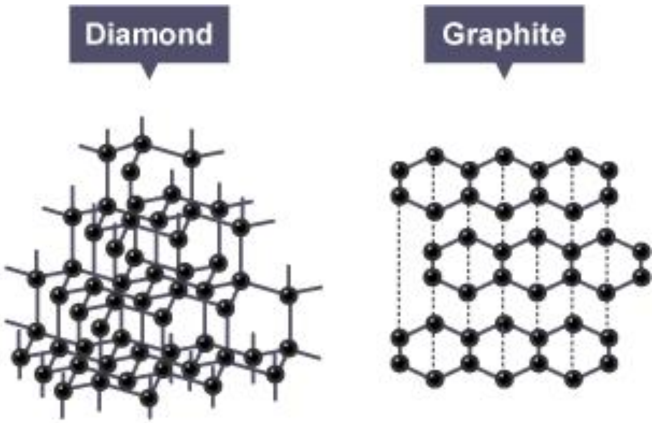



Photo: socratic.org

Photo: wiadomości.wp.pl

Iron:

α 0,286 nm

δ 0,293 nm

γ 0,365 nm

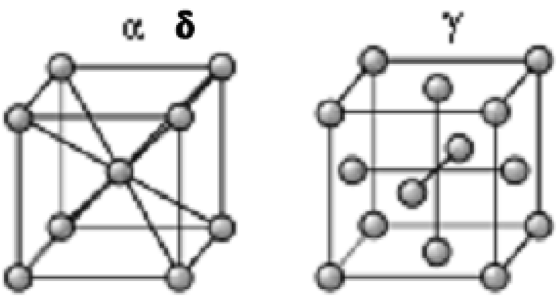



Photo: wikipedia

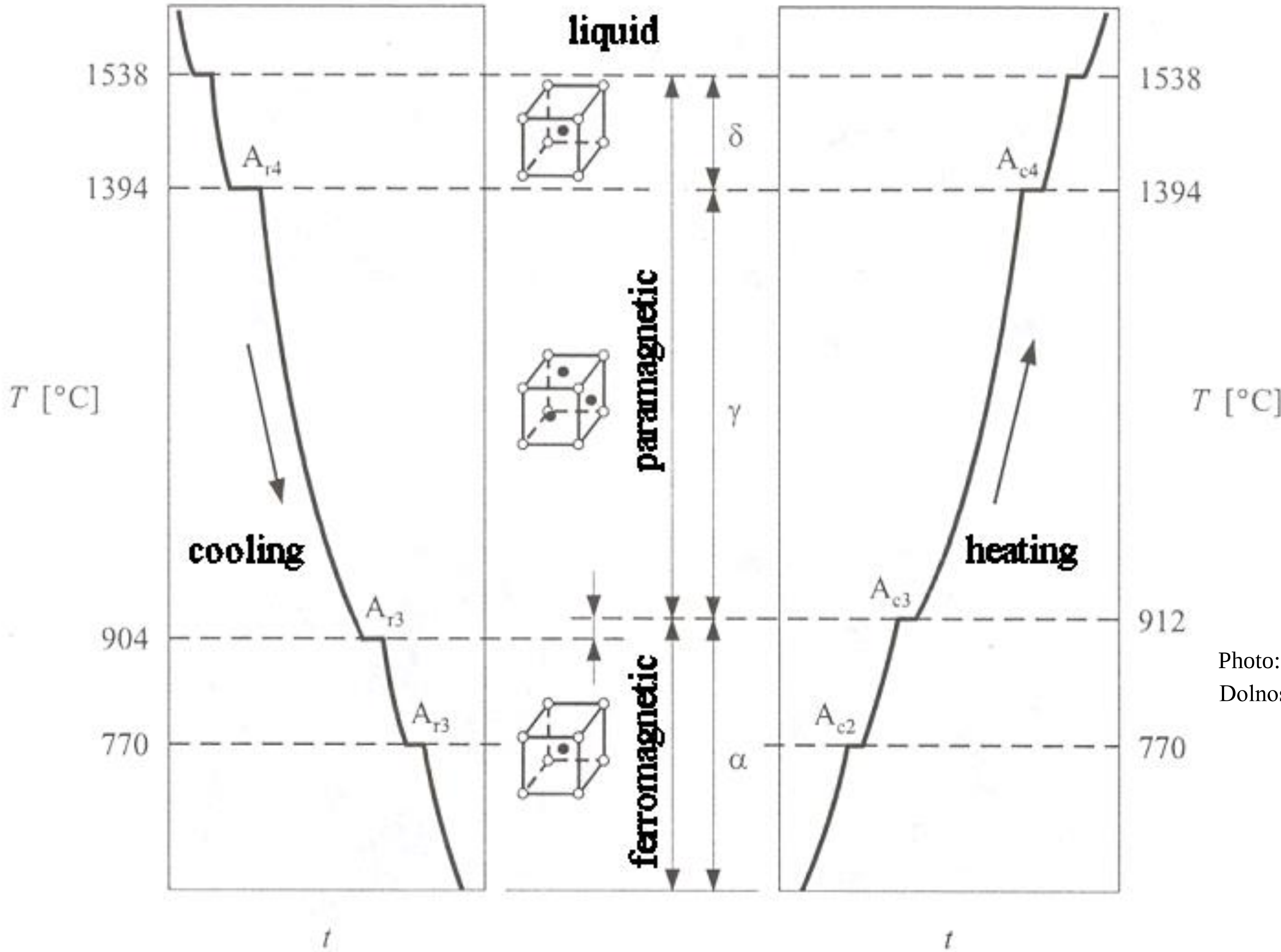



Photo: Konstrukcje stalowe, K. Rykaluk, Dolnośląskie Wydawnictwo Edukacyjne Wrocław 2001

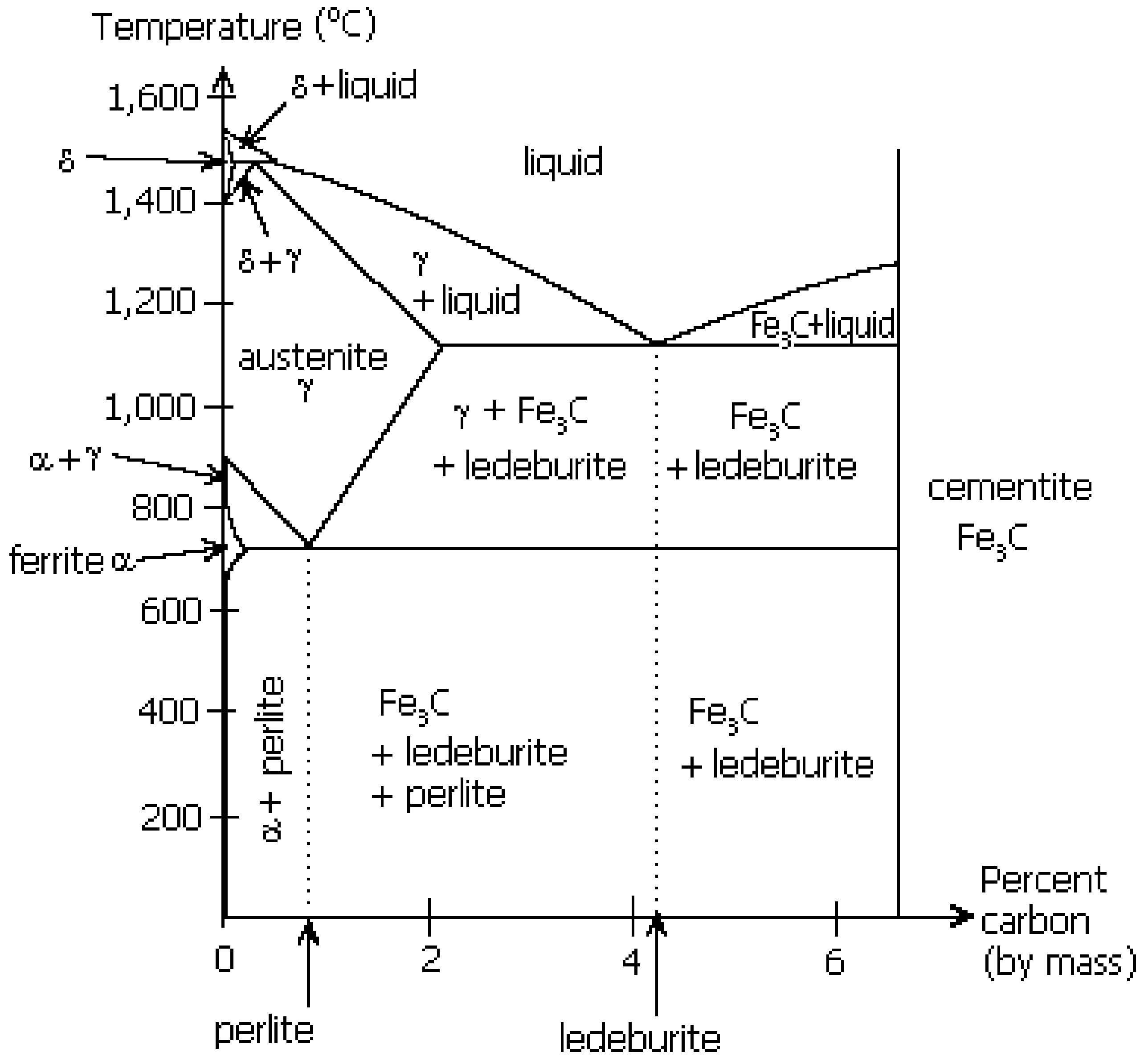



Photo: wikipedia

Ferrite - α-Fe + C (solid solution)

Austenite - γ-Fe + C (solid solution, unstable → pearlite, bainite, martensite, sorbite)

Cementite - $Fe_3C$

Ledeburite = austenite + cementite

Pearlite = ferrite + cementite

Martensite - α-Fe + C

Bainite - similar to pearlite

Sorbite - similar to pearlite

Spheroidyte - balls of cementite in ferrite

More information → Lab. #5

| Name | Mechanical parameters |
| --- | --- |
| Ferrite | Strong, plastic |
| Austenite | Very strong, very plastic |
| Cementite | Hard, fragile |
| Ledeburite | Hard, fragile |
| Pearlite | Finer structure → increase of strength and hardness |
| Martensite | Very hard, too fragile to be used as structure material |
| Bainite | Fragile, not very plastic, not very strong |
| Sorbite | Strong, plastic |
| Spheridoite | Strength and plasticity the lowest among different Fe-C systems |

The best situation for structure steel: high strength, high plasticity, high hardness, very low fragility.

Definitions of these mechanical characteristics → Lec. #2

# Heat treating

Change of mechanical parameters by heating and cooling steel. These precesses change internal structure of steel (recrystallisation). Speed of change of temerature is very important. Color change of the surface it is sometimes a side effect of this process.

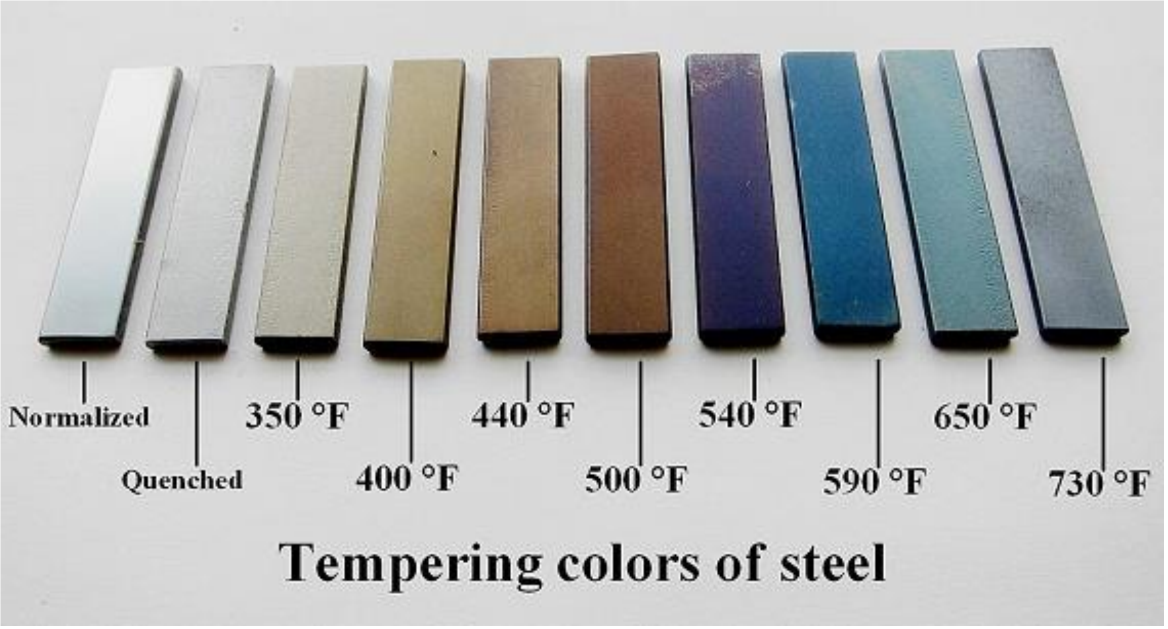
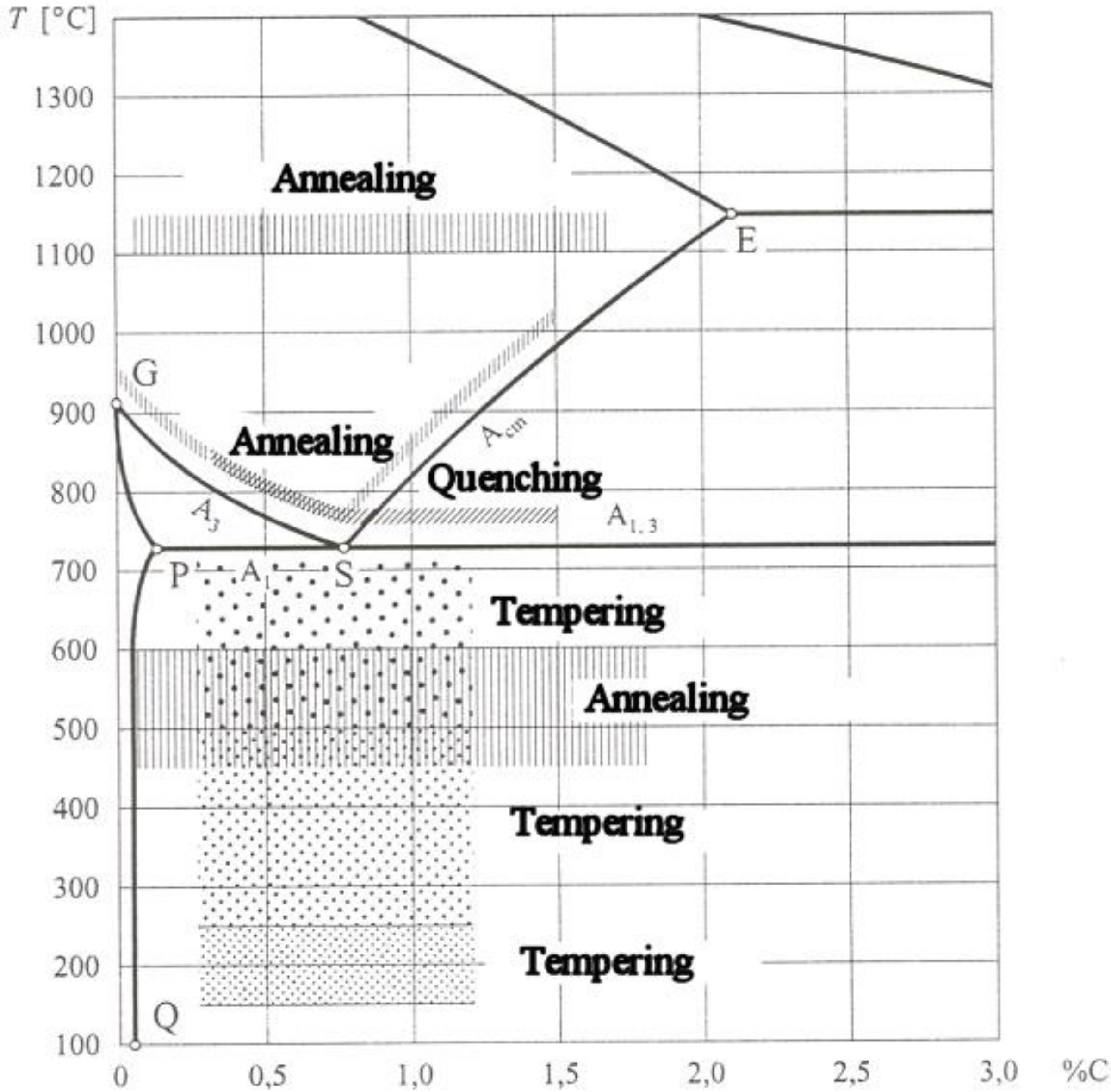



Photo: wikipedia

Photo: wikipedia



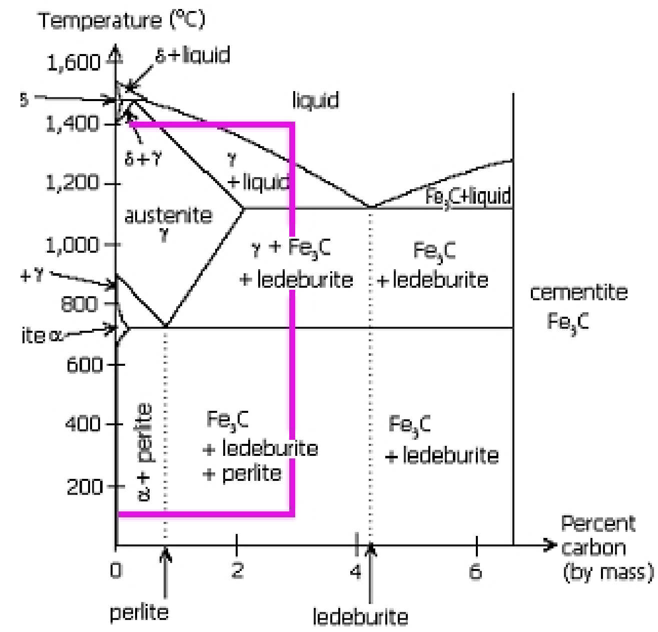




Photo: wikipedia

Photo: Konstrukcje stalowe, K. Rykaluk, Dolnośląskie Wydawnictwo Edukacyjne Wrocław 2001

Annealing – increasing of temeprature, keeping element in this temperature for long time (it's need to change internal structure), very slow decreasing of temperature;

Annealing 1100° C → homogeneous internal structure (chemical and crystalline), homogenize the mechanical characteristics;

Annealing 800 - 100° C → fragmentation of crystals, increasing strength;

Annealing 500 - 600° C → reduction of residual stresses;

Quenching – increasing of temeprature, keeping element in this temperature for long time (it's need to change internal structure), very quick decreasing of temperature → increasing hardness and fragility;

Tempering – increasing of temeprature, keeping element in this temperature for long time (it's need to change internal structure), slow decreasing of temperature;

Tempering 600° C → high strength, decreasing hardness;

Tempering 400° C → high strength, high plasticity, decreasing hardness;

Tempering 200° C → reduction of quenching stresses and fragility, high hardness;

More information → Lab. #5

# Aluminum

Aluminum ore:

Bauxite, $Al(OH)_3$ 50% Al

Photo: wikipedia

Flux:

Cryolite, $Na_3\,Al\,F_6$

Photo: web.natur.cuni.cz

Grinding of bauxite

Bayer process:

$Al(OH)_3 + NaOH \rightarrow NaAl(OH)_4$

(temperature 240 $^oC$, pressure 3,5 MPa)

Calcination (roasting, temperature 1250 $^oC$)

$2\ NaAl(OH)_4 \rightarrow Al_2O_3 + 2\ NaOH + 3\ H_2O$

Hall–Héroult process (electrolysis in molten cryolite, temperature 900 $^oC$)

$2\ Al_2O_3 + 3C \rightarrow 4\ Al + 3\ CO_2$

Rys: web.natur.cuni.cz

| Steel | Aluminum |
|---|---|
| Iron ores, coal (coke) and limestone – rather common minerals | Cryolite – rare mineral |
| Temperatures in blast furnace and during cacination are similar | |
| There is no process under pressure; there are no needed additional chemical reagents | Bayer process: there are needed pressure reactor and chemical reagent |
| There is needed electricity (electric arc furnace / electrolysis) | |
| Thermal processes do not have to be precisely controlled | Pressure and thermal processes must be controlled very precisely |

Rys: uas.su

Effect: aluminum is > 5 x more expensive than „normal” steel.

As in the case of steel, alloying elements are added to aluminum alloys.

Alloying elements → Lec. #2

There is very important type of "heat treating" for aluminium: precipitation hardening (age hardening). The effect of process is increasing of strength and decreasing of plasticity. Increasing of aluminum strength can be up to few dozens %.

Precipitation hardening is devastated during welding. Because of this, heat affected zones (HAZ) must be analysed during calculation of aluminum welding.

HAZ → Lab. #2

# Aluminum profiles

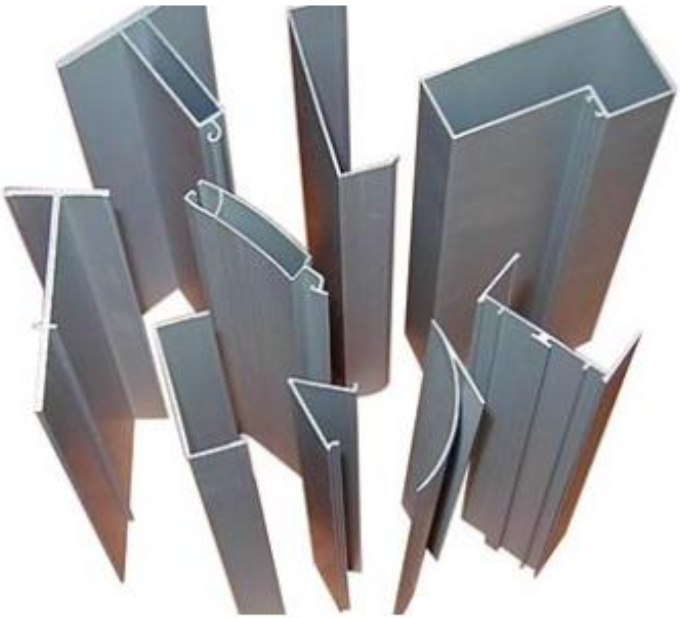


Photo: aluminum-profiles.com

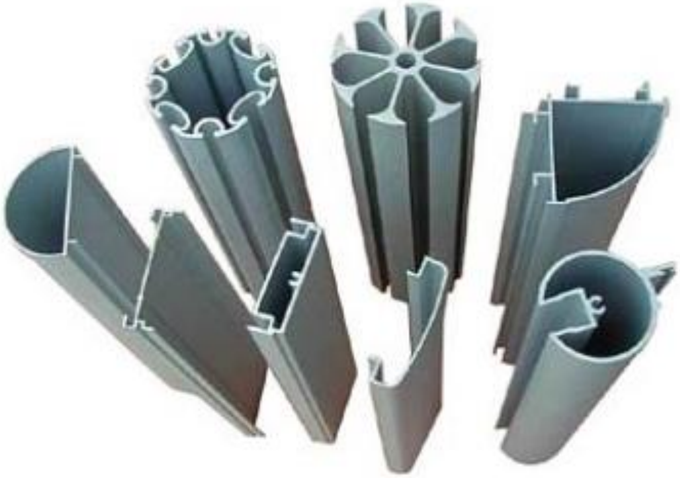


Photo: aluminum-profiles.com

Photo: ecvv.com

Photo: isel.com

Generally, aluminum is used for finishing works: window frames, systems of glass facades, sandwich panels or cladding panels.

Photo: titon.co.uk

Photo: budvar.lodz.pl

Photo: elewacje-stalowe.pl

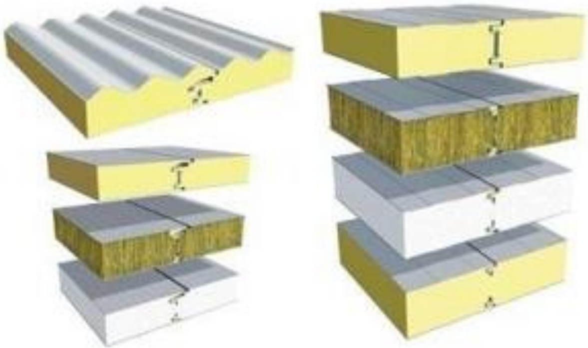


Photo: steelprofil.pl

Photo: ekbud.lublin.pl

# Examination issues

Definitions: steel, cast iron, steel casting

Furnace process, feed materials, products

Definitions: heat treatement, annealing, tempering, quenching

Alloy - stop

Iron - żelazo

Cast iron - żeliwo

Pig iron - surówka

Steel casting - staliwo

Steel - stal

Casting - odlewnictwo

Ore – ruda

Bloomery - dymarka

Blast furnace - wielki piec

Coal – węgiel (surowiec)

Carbon – węgiel (pierwiastek)

Coke – koks

Bloom iron – żelazo dymarkowe

Wrought iron – żelazo kute

Stainless – nierdzewne

Rivet – nit

Bolt – śruba

Welding technology – technologia spawania

Crane – suwnica

Bog ore – ruda darniowa

Mineral processing - wzbogacanie rudy

Open-heart furnace - piec martenowski

Feed materials - wsad

Flux - topnik

Slag - żużel

Scrap - złom

Refining - świeżenie (wypalenie zanieczyszczeń)

Furnace process - proces wielkopiecowy

Ingot - wlewek

Hot-rolled – gorącowalcowane

Cold-formed – zimnogięte

Flange – półka

Web – środnik

Hoop iron - bednarka

Flat steel - płaskownik

Plate riffled - blacha żeberkowa

Plate girder – dźwigar spawany

Corrugated web – środnik falisty

Castellated / cellular beam – belka ażurowa

Pin - sworzeń

Nut - nakrętka

Washer - podkładka

Sandwich panle – płyta warstwowa

Cladding panel – panel okładzinowy

Supercooled - przechłodzony

Heat treatement - obróbka termiczna

Annealing - wyżarzanie

Tempering - odpuszczanie

Quenching - hartowanie

Hardness - twardość

Fragility – kruchość

Precipitatnion hardening - utwardzenie wydzielinowe

Age hardening - starzenie

Thank you for attention



tmichal@pk.edu.pl