Unit 4 (Part 1)
Steel, Galvanization, Cu, Gypsum

Presentations

by

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STEEL

IMP of C%: Alloys, Gdes of Steel

- Steel is alloy of Iron and Carbon whose total Carbon (C) content does not exceed 2%

GRADING and C%

- Steels are graded according to the % of C.
- If C % is smaller its properties resemble Wrought Iron.
- If C% is more, it behaves similar to Cast Iron.
- In ordinary steel, the mech properties are chiefly affected by mod of the C%.
- Steel always contains in min qtys some or all of elements (gen beneficial effects,) Mn, Si, S, P.
- S and P are next in imp to C

IMP of C%: Alloys, Gdes of Steel (Contd)

- Carbon Steel. Steel containing Iron and C only, which is ordy steel.
- Alloy steel. Contains small qtys of other elements such as Ni, Cr, Vd, in addition to C.
- Carbon Steels are roughly divided into 2 cat:
  - Soft Steels with < 0.45% of C.
  - Hard steels with > 0.5% C.
  - (The lesser the C, the softer the steel).
- The proportion of C is varied in the Steels depending on the purpose for which they are required.
  - C is most imp constituent.
  - Gives Str and Hardness,
  - incr of C % decreases Ductility, Malleability and Toughness.
  - Tensile str, Yield pt and elastic limit incr with C%, up to about 1% of C.
  - Higher the C% , lower is the Melting pt.

STEEL - Grades and Classification

- Ordy Structural Steel. 0.24% C and no Alloys (except in min qtys)
- High Tensile Structural Steel. C < 0.3% (0.25% for rivet bars) with Si and Mn up to 1.5%. HT structural Steel bars with Corrosion resisting properties have Cu and Cr in small qtys.
- Gen Cl of Steel as per C%

Ser No	Carbon Content (%)	Name
1	< 0.25	Mild or Soft Steel; Low C Steel
2	0.25 – 0.70	Med C Steel
3	0.70 – 1.25	High C Steel; Tool Steel; Hard Steel
4	> 1.25	Extra-Hard Steel; Very Hard C Steel

STEELS - General Characterstics

- Nature of work vs Type of Steels
  - Rolling into thins sheets. Soft and Malleable Steel is reqd
  - Drawing into Wires. a very soft and ductile steel is reqd
  - Making Tools. A very hard and brittle steel is reqd
- HARDENING.
  - Steels are hardened by heating to redness and quenching in water or oil.
  - Steels respond to 'Heat Treatment' to an incr extent as the C % is incr
  - But, very low Carbon Steels and Wrought Irons with C< 0.2% cannot be hardened or tempered…. however, they can be 'Case Hardened'.
  - 'Case Hardened Steel' has a surface with enriched C%. Resistant to 'surface wear'.
  - Degree of Hardness obtained depends upon the C %
  - By Hardening, Steels become more or less brittle,
  - They can be hardened and tempered and are fusible at a lower temp than wrought iron … and retain magnetic properties.

STEELS - General Characterstics

- ANNEALING. They can be annealed or softenend by heating to redness and cooling slowly.
- WELDING. Steels are highly elastic, ductile, malleable, forgeable and weldable. Steels containing less C can be welded more easily
- SMITHING. Smithing of steel is more difficult than wrought iron and it is more liable to injury from over-heating.
- WEAR AND TEAR. Steels have much higher tensile and compr str than wrought iron and stand wear and tear much better.
- DRILLING AND PUNCHING. Steel plates sustain greater injury when punched than wrought iron, therefore holes should be drilled in steel plates as fare as possible.

MILD STEEL: Properties and Uses

- Also known as Low Carbon Steel or Soft Steel.
- It is
  - *Ductile.* Can be drawn into Wires (+)
  - *Malleable*. Can be drawn into Sheets (+)
  - *Tougher* and more *Elastic* than Wrought Iron. (*Toughness* indicates energy that a material can absorb before fracture) (+)
  - can be *Forged* and *Welded*. (*Forging* is ability to be shaped by Heating and Hammering). (+)
  - can be permanently Magnetized. (+)
  - difficult to *Temper* and *Harden.* (-)
    - *Tempering* is reducing the brittleness of Steel by Heating
    - *Hardness* indicates easiness/ difficulty with which surface can be scratched.
  - Rusts quickly (-)

MILD STEEL: Properties and Uses

- Properties are:
  - Sp. gr. 7.30
  - Ultimate Compressive and Tensile strengths 800–1200N/mm2 and 600–800N/mm2.
- Used in the form of
  - Rolled sections
  - Reinforcing bars
  - Roof coverings (CGI sheets etc)
  - Sheet piles
  - in Railway Tracks.

Rolled Structural Shapes

1.	Rolled steel I-sections	Fig. 13.5(a)
2.	Rolled steel channel sections	Fig. 13.5 (b)
3.	Rolled steel T-sections	Fig. 13.5 (c)
4.	Rolled steel angle-sections	Fig. 13.5 (d)
5.	Rolled steel tube-sections	Fig 13.5 (e)
6.	Rolled steel bars	Fig. 13.5 (f)
7.	Rolled steel flats	Fig. 13.5 (g)
8.	Rolled steel plates	
9.	Rolled steel sheets	
10.	Rolled steel strip	

1. Steel pre-rolled into various shapes as shown.
2. Sections are divided into Heavy, Medium and Light sections
3. Std Design tables are Available as per BIS. Design, Mfr, Execution, QA/ AC and Audit are done as per These Std tables.

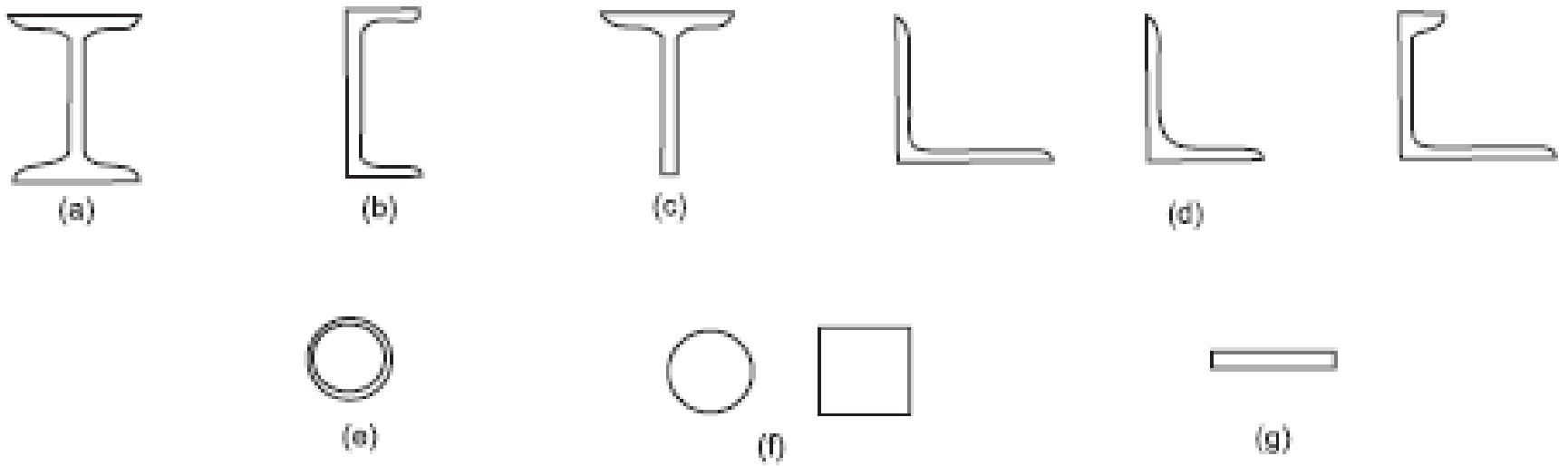


Fig. 13.5 Rolled Structural Shapes

HYSD Bars

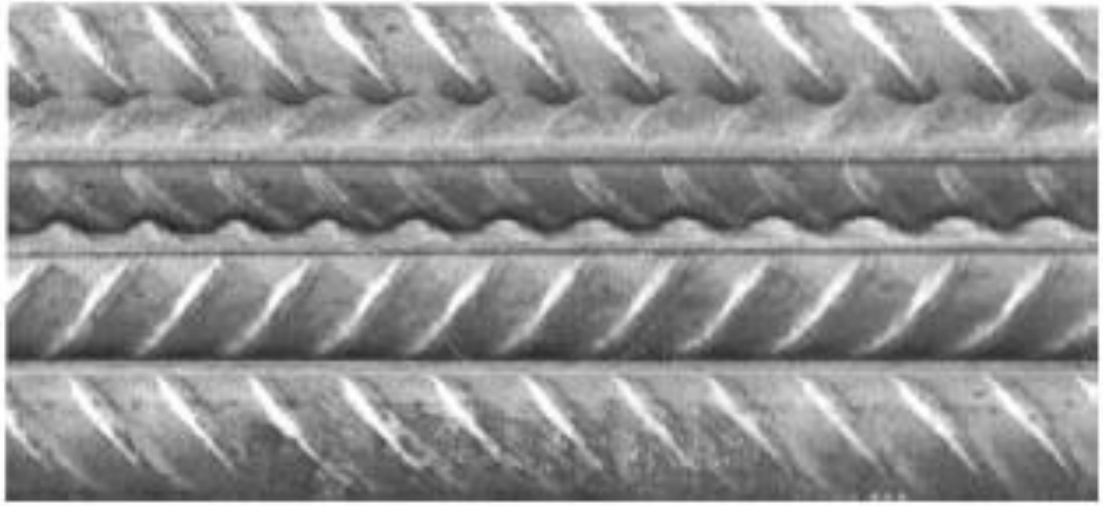


Fig. 13.6 High yield strength deforemd bars

Sheet Piling

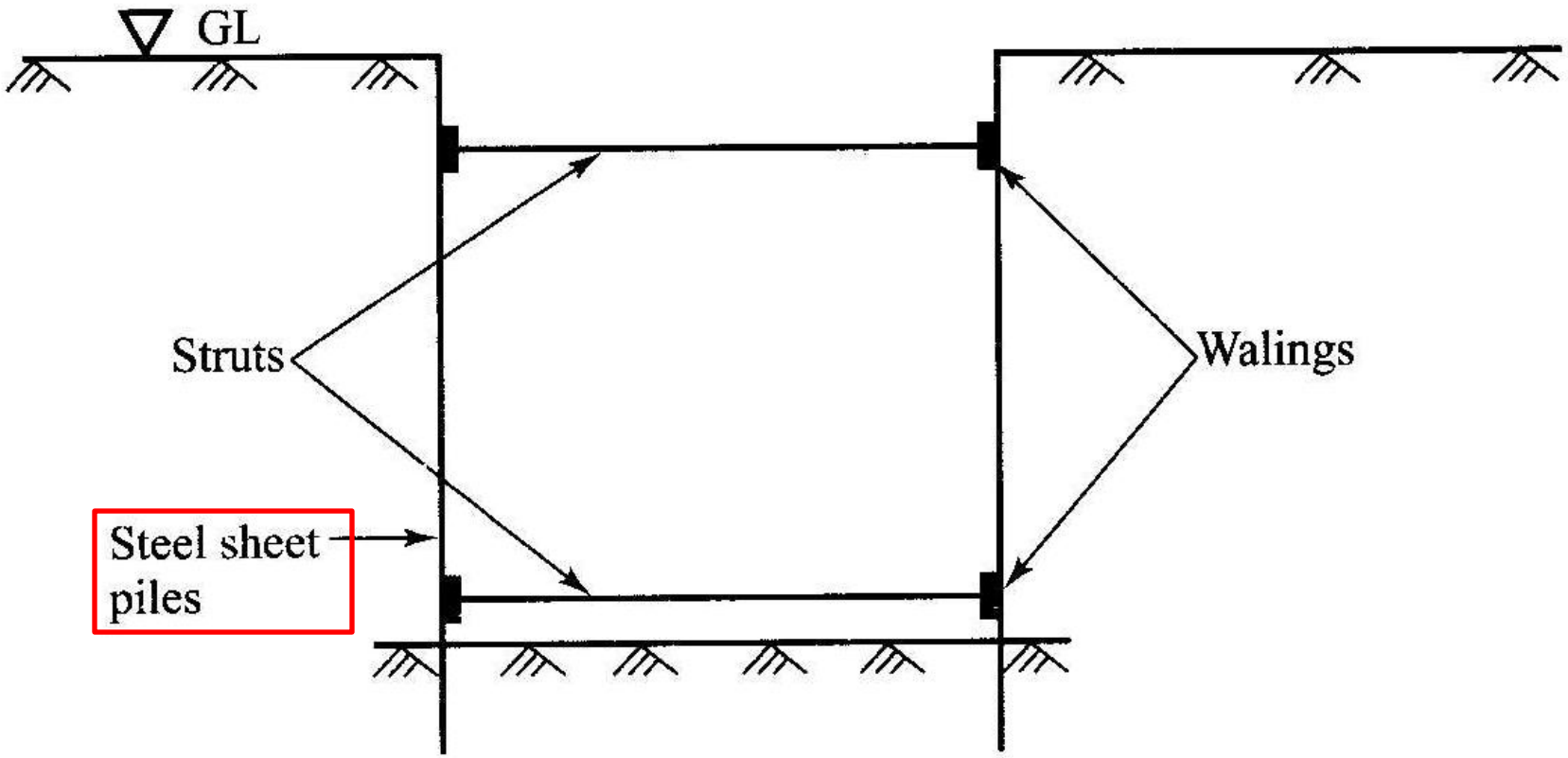


Fig. 4.6 Sheet piling

Sheet Piling _ Single Skin Cofferdam

WORKING SPACE SECURED BY SHEET PILING

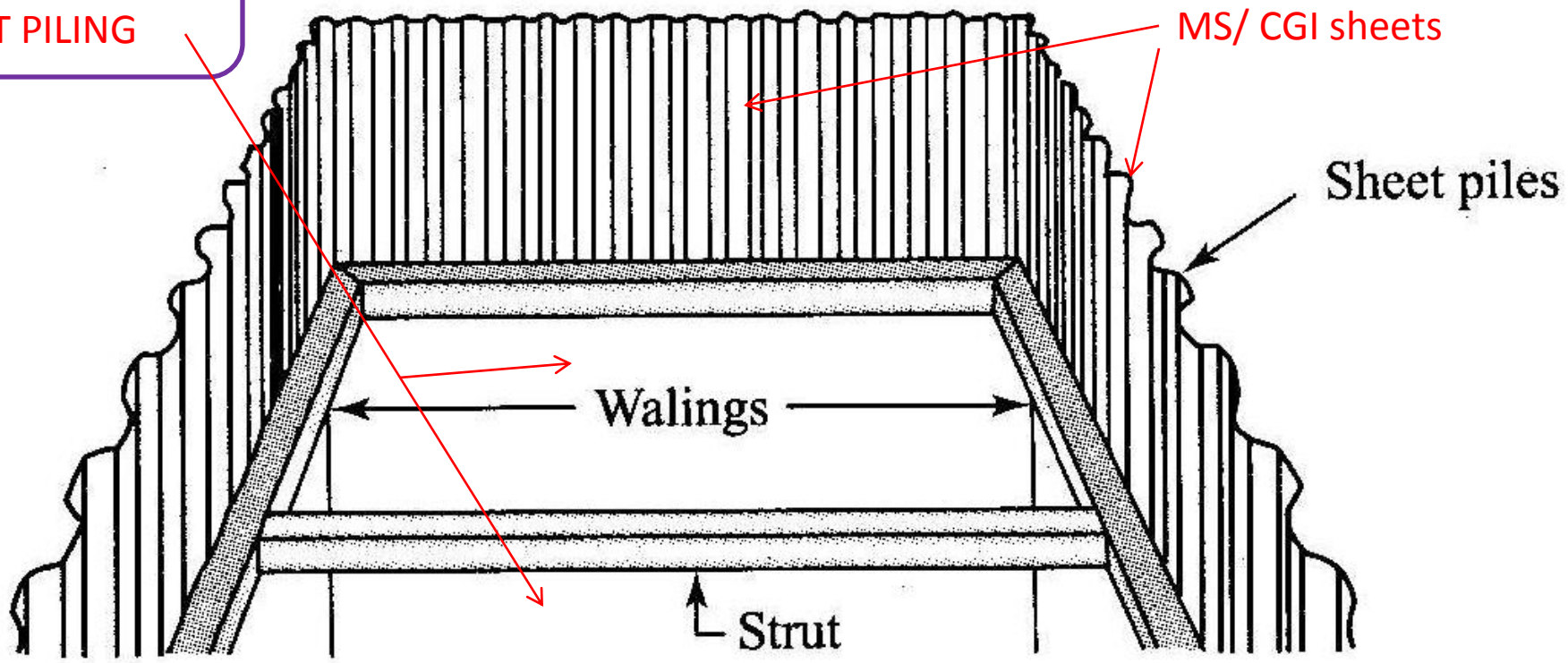


Fig. 4.7 Single skin cofferdam

Sheet Piling _ Double Skin cofferdam

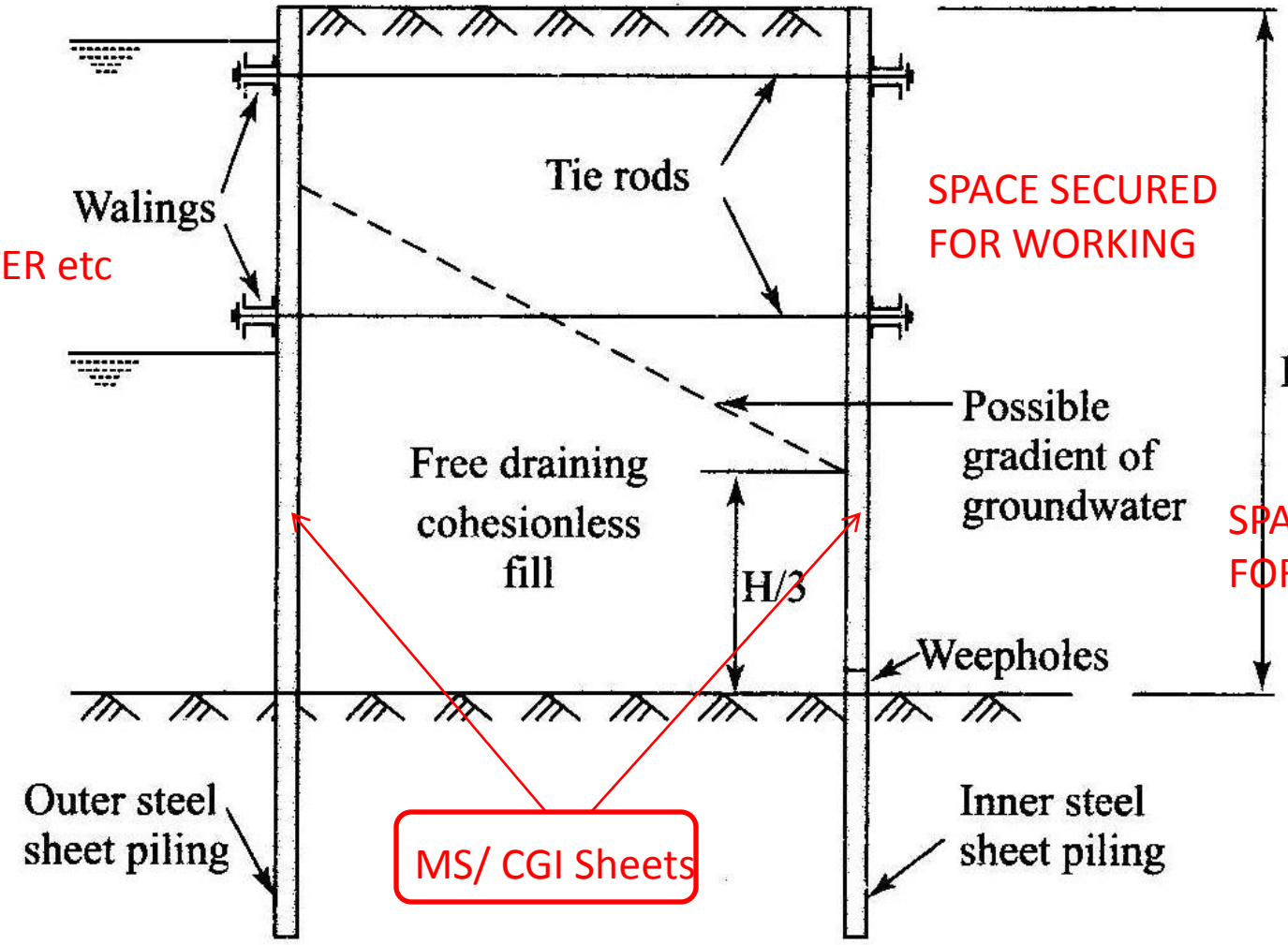


Fig. 4.8 Double skin cofferdam

Rail Sections

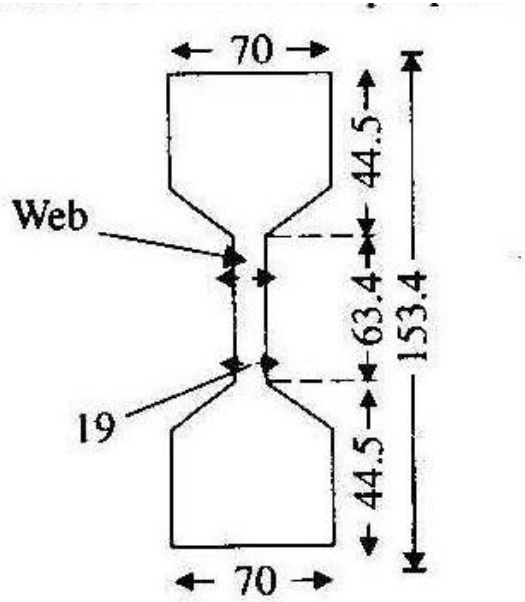


Fig. 5.1. Double Headed Rail.

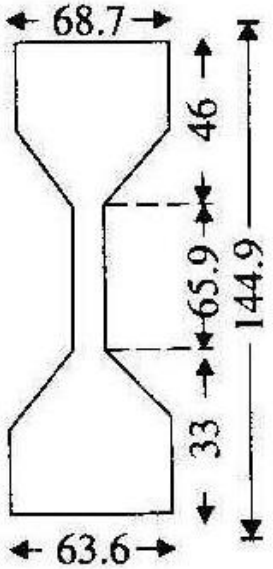


Fig. 5.2. Bull Headed Rail.

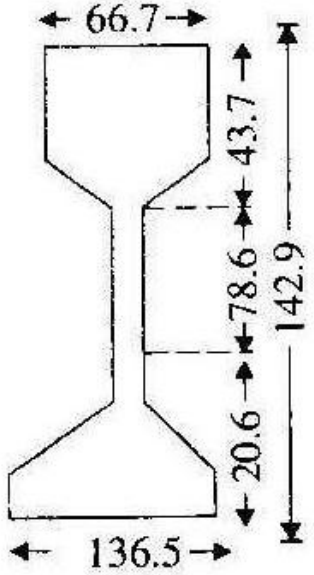


Fig. 5.3. F.F. Rails.

High Carbon Steel: Properties and Uses

- Carbon content. 0.55 to 1.50%. (More)
- Also known as Hard Steel. It is Tougher and more Elastic than mild steel. (+)
- Can be Forged and Welded with difficulty. (-)
- Its Ultimate Compressive and Tensile strengths are 1350 N/mm2 and 1400–2000 N/mm2, respectively. (+)
- Sp. gr. is 7.90. (++)
- Used for RCC and Prestressed Concrete members.
- Can take Shocks and Vibrations (++)
- Used for making Tools and Machine parts. (++)

High Tensile Steel: Properties and Uses

- Composition
  - C. 0.6–0.8%
  - Mn. 0.6%
  - Si. 0.2%
  - S. 0.05%
  - P. 0.05%.
- Also known as 'high strength steel' and is essentially a 'medium carbon steel'. (+)
- The Ultimate Tensile Strength is of the order of 2000 N/mm2 (+)
- Min Elongation. 10% (+)
- Used in Prestressed Concrete Construction. (++)

Types and Gdes of Rft Bars

Table 13.2 Types and Grades of Reinforcing Bars

Types of steel	*Bar diameter*	*Yield stress or 0.2% proof stress*	*Minimum elongation*
1. Mild steel grade-I	Upto and including 20 mm	250 N/mm^2	23%
	Over 20 mm upto and including 50 mm	240 N/mm^2	23%
2. Mild steel grade-II	Upto and including 20 mm	225 N/mm^2	23%
	Over 20 mm upto and including 50 mm	215 N/mm^2	23%
3. Medium tensile steel	Upto and including 16 mm	350 N/mm^2	20%
	Over 16 mm upto and including 32 mm	340 N/mm^2	20%
	Upto and including 50 mm	330 N/mm^2	20%
4. High strength deformed steel bars	All sizes	415 N/mm^2 500 N/mm^2 550 N/mm^2	14.5% 8% 6%
5. TMT Bars	All sizes	415 N/mm^2 500 N/mm^2 550 N/mm^2	22% 20% 18%

STRESS-STRAIN CURVE OF A METAL

Ultimate Tensile Strength

Yield Strength

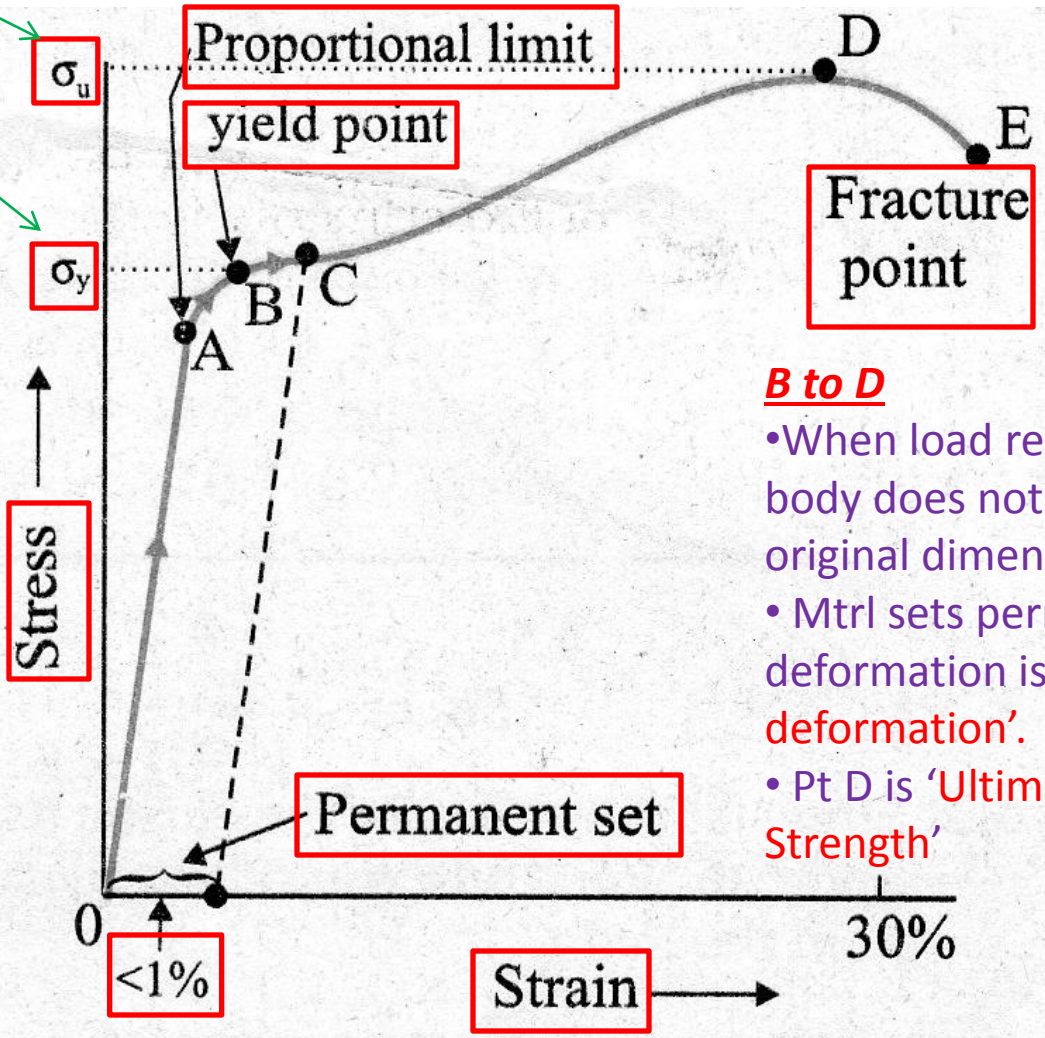
O to A

Curve is linear

Hooke's Law is obeyed

A to B

- Stress Strain NOT proportional
- However, Body still returns to its original dimension, when Load is removed
- B is called 'Yield Pt'. (Elastic Limit)
- Stress at B is called 'Yield Strength'



B to D

- When load removed, the body does not regain its original dimension.
- Mtrl sets permanently. The deformation is called 'Plastic deformation'.
- Pt D is 'Ultimate Tensile Strength'

Fig. 10.3 A typical stress-strain curve for a metal.

CLASSIFICATION

- Steel for reinforcing bars can be classified according to its USE.

MILD STEEL

- The earliest steel used for construction purposes was plain *mild steel bars, designated as Fe- 250 and so. Even nowadays* it is as engineers friendly as before in the underdeveloped and developing countries.
- For impacts and suddenly applied loads mild steel reinforcement may prove to be a better choice since high yield steels are more brittle and may fail under such conditions

HYSD BARS

High Yield Strength Deformed (HYSD) Steel Bars

- have lugs, ribs, or deformations on the surface (Fig. 13.6), which inhibit longitudinal movement of the bar relative to the surrounding concrete. Thus, the deformed surface ensures better bond between reinforcement and concrete. (++)
- These bars do not have a definite Yield Point.
- HYSD bars result in a considerable increase in Yield, Tensile and Bond strength when twisted hot or cold. (+)
- Cold Twisted Deformed (CTD) bars are most suitable for building purposes and are widely used in India. CTD bars with trademark TOR are called *TOR-steel*. (+)
- *Tor-steel is HYSD bars with high Yield and Bond* strength. (++)
- These bars result in almost 40% economy. (++)

HYSD Bars *(Contd)*

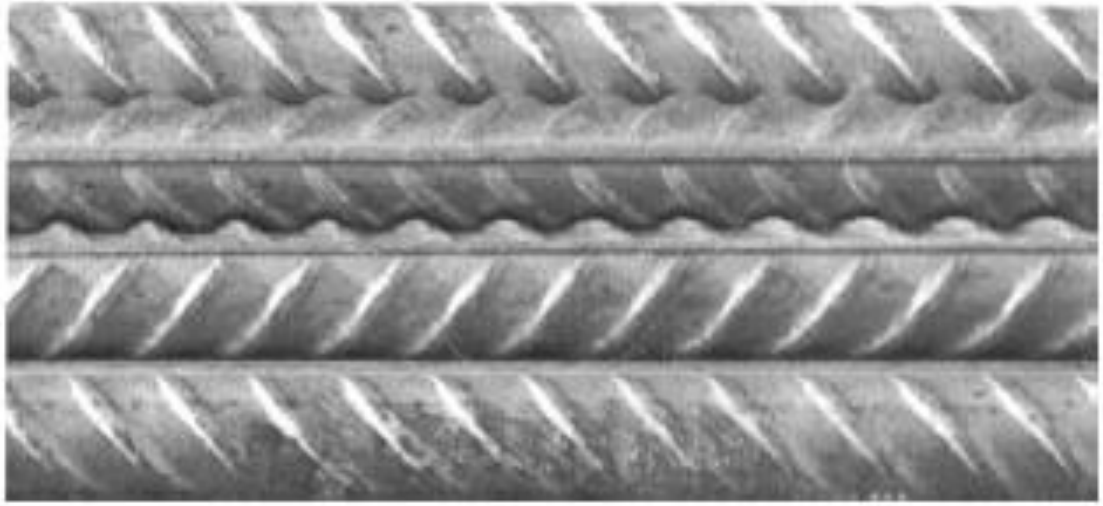


Fig. 13.6 High yield strength deforemd bars

TMT Bars

Thermo-Mechanically Treated Bars

Mfg Process

- Step 1. Steel bars receive a short intensive cooling as they pass through a water cooling system after the last rolling mill stand. The reduction in temperature converts the surface layer of the steel bar into a hardened structure.
- Step 2. Cooling in atmosphere, so that the temperature of core (which is still hot) and the temperature of the cooled surface is equalized. Hence, the surface layer gets tempered by the heat form the core. (*Tempering* is reducing the brittleness of Steel by Heating)
- The resulting structure is
  - a tempered Martensite zone at the periphery, and
  - a fine grain ferrite Pearlite structure in the centre zone.

Martensite and Pearlite

- Martensite.
  - Steel of a distinguishable Needle-like Micro-structure, particularly so when quenched from high temp.
  - It is Hard, Strong and Brittle and very resistant to Abrasion and Deformation. (++)
  - Martensitic stainless steels are of this structure containing Cr but not Ni.
- Pearlite. Iron, a mixture of fine grained Ferrite and Cementite with a C% of about 0.78 by wt.

TMT Bars *(Contd)*

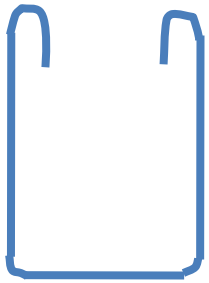
Due to High Strength combined with Toughness and Ductility,

TMT bars score over Mild Steel, Plain and CTD (Cold Twisted Deformed) Steel bars.

TMT Steel Bars

- Yield Pt. exhibit a definite yield point. (+)
- Resistance to Temp. can resist up to 500°C, with no loss of strength. (+)
- Ductility. are more Ductile compared to CTD bars. (+)
- Bend ability.
  - possess excellent Bend ability due to the unique feature of uniform elongation. (++)
  - They can withstand bending and re-bending with internal diameter of 1D and 4D respectively (D = diameter of the bar).
- Weld ability. Very Good (++)
  - They do not suffer loss of strength at the weld joints.
  - These bars can also be easily Welded with CTD bars. (+)
  - No pre-heating, or, post-heating is required during Welding. (+)

Some Bends in Rod Bending



TMT Bars *(Contd)*

- The ***UNIQUE feature*** of these bars is their high fatigue resistance on dynamic loading on account of the high strength of the surface layer. (Due to Martensite zone) (++)
- Fire Resistance. The thermally hardened reinforcing steel bars are more suitable for use in places prone to fire hazards, because of (+)
  - the thermal stability of the heat treated structure of the bars
  - A total absence of a cold worked structural zone.
- Elongation. TMT bars have high percentage of uniform elongation — thus high formability. (+)
- Places of USE.
  - These bars can be used for general concrete reinforcement in buildings, bridges and various other concrete structures. (+)
  - They are highly recommended for use in high-rise buildings because of the saving in steel due to the higher strength. (++)
- A comparison for saving in steel by using TMT bars is given in Table 13.3. (++)

Use of TMT BARS _SAVING in STEEL

Table 13.3 Saving in Steel by using TMT Bars

	TMT 415	*TMT 500*	*TMT 550*
Yield strength, MPa, Min	415	500	550
Saving in steel compared to Plain bar	40%	44%	47%
Saving in steel compared to Fe-415 CTD	–	14%	19%

TMT-HCR Bars

- The latest development is steel reinforcing bars is *Thermo-Mechanically treated High-Strength Corrosion Resistant (TMT-HCR) rebars.*
- *The TMT-HCR re-bars are concrete embedded bars,* which have superior resistance to aggressive weather conditions. (++)
- Thermal Resistance. Up to 600°C. (+)
- Resistance to Softening.
  - High. The retention of significant strength or, in other words, resistance to softening attributed to design of steel chemistry, (+)
    - presence of tempered Martensite layer of the rebar surface and
    - absence of any cold worked structural zone.

TMT-HCR Bars

- Corrosion Resistance. (++)
  - High.
  - The Chemistry of TMT-HCR re-bars is appropriately designed for substantially reducing atmospheric and marine corrosion.
  - Compared to conventional CTD bars, TMT-HCR re-bars exhibit Superior Corrosion Resistance owing to the absence of Torsional stresses in Thermo-Mechanically treated re-bars and design of suitable Alloy Chemistry.
- Strength, Ductility and Bend ability. (+)
  - High
  - A unique combination, which testifies the product's Toughness and ease of Fabrication.
- Bend ability. (+)
  - Excellent.
  - Found to withstand even close bend, without exhibiting surface cracking.

TMT – HCR Bars

- Bond Strength. (+)
  - Excellent.
  - The Rib pattern of these re-bars ensures excellent bond strength between the rebar surface and concrete
  - fulfils the requirements of Indian specifications.
- Fire Hazards. The thermally hardened TMT-HCR re-bars are ideal for use in places prone to fire hazards. (+)
- Weld ability. These re-bars can be easily welded and do not require pre-heating or post-heating treatments. These bars can also be welded with conventional CTD bars, permitting usage independently (or) in combination in reinforcement structures. (+)

TMT – HCR Bars _ Advantages

- Advantages of TMT-HCR re-bars over conventional CTD re-bars are many.
  - saving in steel,
  - reduction in costs,
  - enhanced strength combined with high ductility,
  - superior atmospheric and marine corrosion resistance,
  - good weld ability
  - no loss of strength at welded joints
  - better high temperature thermal resistance
  - easy welding at site owing to better ductility and bend ability.

TMT - HCR Bars _ Application Areas

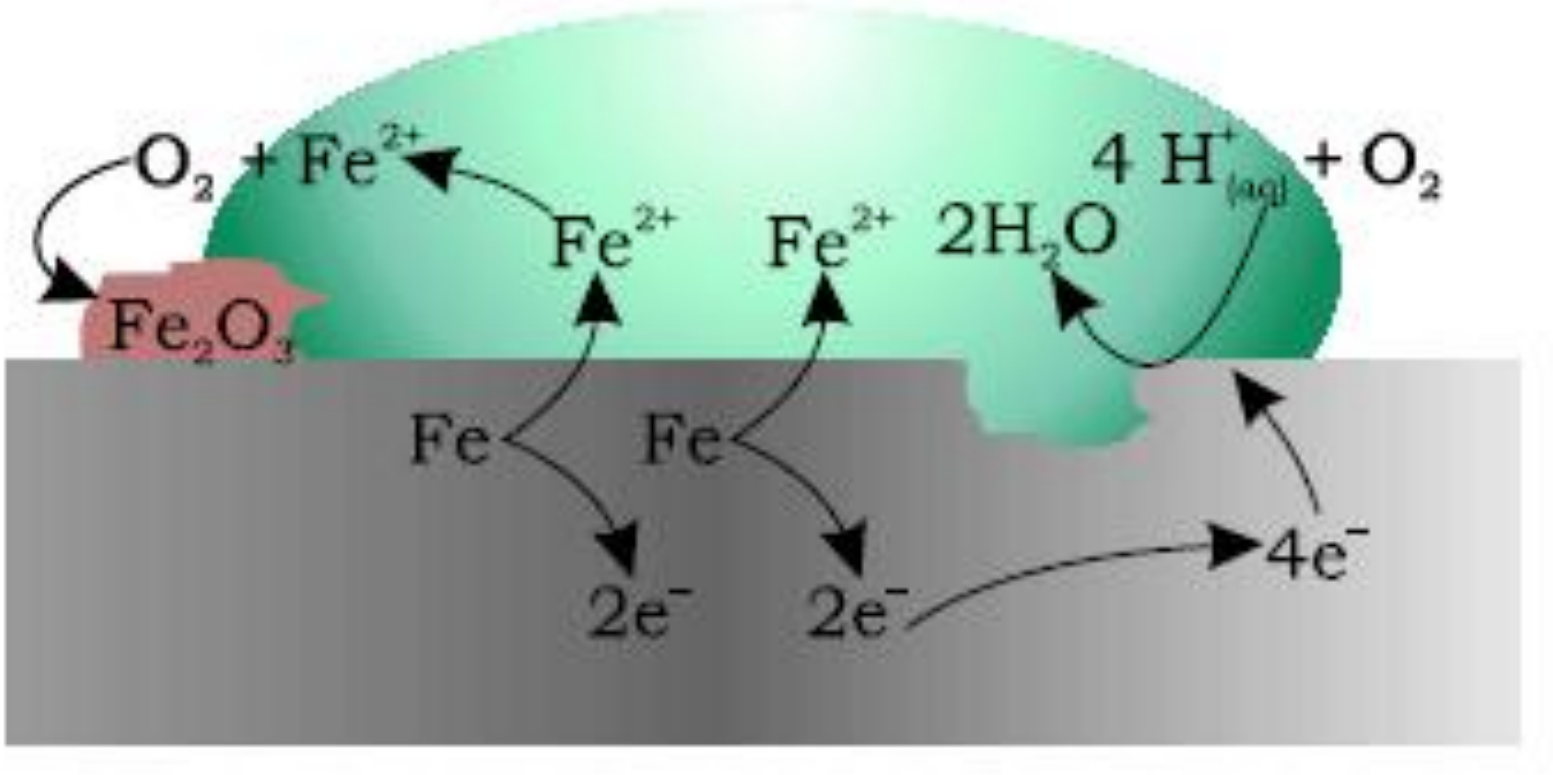
Application Areas. in different spheres including

- Due to High Strength
  - Bridges,
  - Flyovers,
  - Dams
  - Industrial Structures
  - High Rise Buildings
- Due to Corrosion Resistance
  - Coastal and Marine environments which are susceptible to corrosion,
  - Underground platforms.

IRON AND STEEL - RUSTING

- Rust
  - Hydrated Oxide of Iron and a product of corrosion.
  - Oxygen and moisture are necessary for rusting of Iron.
- Rusting and C% _ Relation.
  - Rusting has some direct relation with Carbon content of Iron.
  - Pure Iron resists corrosion and rusting much better than a medium carbon steel. Usually Steel rusts more easily than Wrought Iron.
  - There is little difference between good Wrought Iron and Steel when exposed to
    - Atmosphere
    - Sea Water
    - as pipes in Water Supply systems.
- Cast Iron offers excellent resistance to corrosion than any other ferrous metal; Cast Iron water mains is an example. (++)

CORROSION MECHANISM



IRON AND STEEL - RUSTING

- Pores or cracks in the surface induce Corrosion.
  - Mtrl whose structure is uniform resists corrosion better than one having a non-uniform structure.
  - A Hardened Steel does not rust so readily as when the same steel has been Annealed because its structure is more uniform.
  - Annealing. The process of heating and slow cooling of metal or glass to reduce internal stresses, to soften and reduce brittleness, residual stresses and weaknesses during e.g., Welding, Casting, Machining
- In locations where structural steel is exposed to excessive Atm Corrosion , ***Cu bearing steel*** may be used,
  - Cu content. 0.20 to 0.35%.
  - As suitable as Mild Steel and only slightly more expensive, but have resistance to corrosion at least twice that of mild steel.
  - Now employed to give long life to Steel Sheet Piling.

GALVANIZED IRON

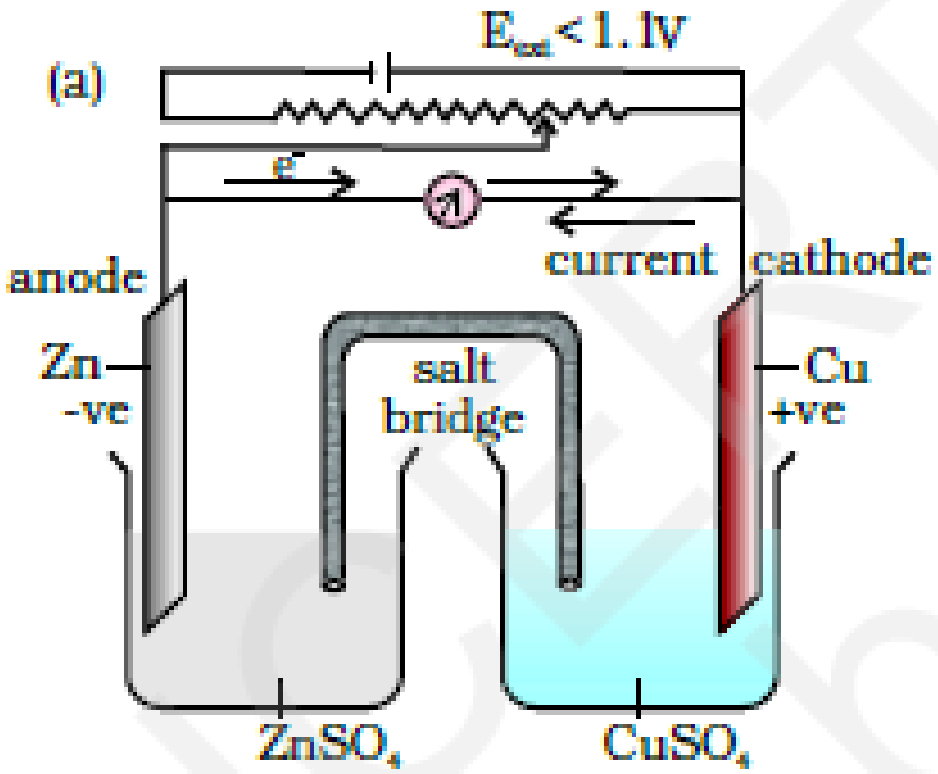
Galvanizing (Zinc Plating)

- Surface of Iron or Steel is coated with a thin layer of Zn to protect it against corrosion
- 2 processes.
  - Hot Dip Galvanizing and
  - Electro Galvanizing (Cold Process)
- Hot Dip Process.
  - Article is cleaned with a layer of Ammonium Chloride (Sal-Ammoniac), and dipped in Molten Zn. This produces a skin of Zn alloyed to the Steel.
  - A small qty of 'Al' is gen added to the molten Zn.
  - Amt of Zn coating varies from 300 to 750 gms/ sq m (GSM), both sides incl.
  - With the Hot process; Ductility and Tensile Str of fine Gauge wires or sheets is reduced

Galvanizing (Zinc Plating)

- Electro Galvanizing .
  - A process of 'Zn' plated similar to other forms of Electro plating.
  - The coating produced is an improvement upon that produced by the Hot process
  - the film of Zn although ample to protect from Oxidation…. is porous and inferior to that prod by the Hot dip process..
- Zn will not adhere on a dirty surface or scaly places and will blister or leave out uncoated patches

Electro Plating



When $E_{ext} < 1.1$ V

(i) Electrons flow from Zn rod to Cu rod hence current flows from Cu to Zn.

(ii) Zn dissolves at anode and copper deposits at cathode.

SHERADISING (Dry Galvanizing)

- This is also know as Cementation (coating) process
- A process of coating articles with Zn; by pickling them in Zn dust and heating to 300 deg C.
- Process.
  - Articles to be coated are first dipped in an Acid bath.
  - Later, pickled with Zn dust.
  - Zn combines with the surface of the metal at a temp below the melting pt of Zn which slightly hardens the metal superficially.
  - Coating is very durable and can be polished.

COPPER

Cu-Properties

- Copper is a bright shining metal of Reddish colour which turns greenish on exposure to weather.
- Ideal material for many purposes and next in importance to Iron for Engg wks.
- It is Light, Tough, Strong, Very Malleable and Ductile, and can be worked in Hot and Cold conditions.
- Thermal and Electrical conductivity. High. Second to Silver, and is therefore very widely used for Electrical wires and Cables.
- Electrical Resistivity .
  - Less. Lies between 0.155–0.159 ohm per metre gram at 20° C. (Copper having less than 0.1 per cent non-metallic impurities).
  - The Resistivity increases with the content of impurities and with amount of wire drawing.

Cu-Properties

- Corrosion Resistance.
  - Good, in dry air.
  - Is attacked by Acids but stands well Sea Water.
- Weld ability.
  - 'Cu' can be forged, rolled or otherwise worked hot or Cold and drawn into Wires, but cannot be Welded.
  - Joints are made either by soft or hard Soldering.
- Tensile Strength is high.

USES

- Electrical Wires and Cables
- Light Gauge Tubing for Hot and cold water-supply, Gas and Sanitation services
- Roofing Sheets
- Alloy of Cu and Zn with over 50% of Cu is termed Brass. Brass has following uses:
  - Stop cocks and valves in Water wks
  - Bearings for machinery
  - Fittings for Doors and Windows
  - House hold Utencils.
  - Available in the form of Sheets, Strips, Wires, Rods and Castings; which can be used as per requirement at Site.

GYPSUM

GYPSUM

- Hydrated Calcium Sulphate, $CaSO_4 . 2H_2O$
- Occurs naturally in Crystalline form
- Used as Plaster as a surface finish for Ceilings and Walls and in Plasterboard.
- Forms Plaster of Paris, when heated

EFFECT OF HEAT AND MOISTURE

- The water of crystallization in the gypsum (CaSO4 2H2O) is not held firmly by the mineral. Therefore, when it is heated to about 160°C it loses a part of water of crystallization and is known as *half-hydrate gypsum.*

$$2CaSO.\ 2H\ O \xrightarrow{160^\circ C} 2CaSo\ 4.\ \tfrac{1}{2}\ H2O + 3\ H2O$$

Gypsum — Plaster of Paris

- At still higher temperatures (About 200°C), Gypsum loses all its water of crystallization and turns out into anhydrate Gypsum.

$$CaSO4\ \ 2H2O \xrightarrow{200^\circ C} CaSO4$$

- The lost water of crystallization can be regained under favorable damp or moist conditions.

$$2\ CaSO\ 4.\ \tfrac{1}{2}\ H\ O + 2\ H2O \xrightarrow{\text{Hydration}} 2CaSO4.\ 2H2O$$

$$CaSO4 + 2H2O \longrightarrow CaSO4.\ \ 2H2O$$

GYPSUM- Varieties

Gypsum binders are classified as

- Low Burning
- High Burning

- Low Burning Variety
  - Mfd by heating de-hydrated Gypsum to a temperature of about 160°C.
  - E.g. Building and Extra Strong Gypsums.
- High Burning (anhydrite) variety
  - Mfd by burning dehydrated Gypsum at 700°C–*1000°C*,
  - *when the Chemically* bound Water is lost totally.

GYPSUM- Clasification

Gypsum may also be classified as

- Low Strength Gypsum
- *Extra Strong Gypsum*

- Low Strength Gypsum
  - Mfd by heating Natural Gypsum Rock at normal Pressure,
  - Very Hygroscopic (60–*65%) and Porous (40%)*
- *Extra Strong Gypsum—*
  - *Mfd by heating* Gypsum at Pressure of 2–*3 atm, followed by drying at 160°C–180°C*
  - Used in Metallurgical Industries for mfr of Moulds.

GYPSUM_ Properties

(+)

- Bulk Density. Relatively Small. (Bulk Density means Wt of mtrl per unit vol, incl Water, Air Voids and Solids
- Combustibility. Not combustible.
- Sound Absorbing Capacity. Good
- Fire Resistance. Good
- Shrinkage. Negligible, even on rapid Drying and Hardening
- Surface Finish. Superior
- Resistance to Insects and Rodents . Good
- Low energy input during burning to produce Gypsum Plaster.

(-)

- poor Strength in Wet state
- high Creep under Load. (***Creep*** is permt deformation at high temp, or, under Load)

GYPSUM_ Uses

- Wall Construction
  - Gypsum plaster, *e.g., Plaster of Paris*
  - Wall Plaster Stucco .A sturdy type of Plaster used on exterior walls, often spread in a decorative pattern
  - Hard finish Plaster
- Flooring plaster, made by Calcining Gypsum at a High Temperature.
- Gypsum in a more or less dehydrated state is the essential element, in all of these powders.
- Gypsum based items should be used only in
  - Dry state and
  - when Relative Air Humidity < 60% .