

# Course on Nature and Properties of Materials

**Instructor : *Prof. Bishakh Bhattacharya***

Department of Mechanical Engineering  
IIT Kanpur, India

**E-mail:** *bishakh@iitk.ac.in*



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# Course References

## *Textbook*

- I. *Materials Science and Engineering: An Introduction*, **William D. Callister (Jr.)**, Pub. John Wiley & Sons, Inc.

## *Reference books*

- I. *Engineering Materials 1: An Introduction to Properties, Application and Design*, Michael F **Ashby** and David R. H. **Jones**, Pub. Elsevier.
- II. *Materials Selection in Mechanical Design* by Michael F. **Ashby**, Pub. Elsevier.
- III. *Mechanics of Composite material*, **Robert M. Jones**, Pub. Taylor & Francis.
- IV. *Smart Structures Theory* by **Inderjit Chopra & Jayant Sirohi**, Cambridge press.



# Course Plan

Two Quizzes – 5% + 5%

MidSem – 20%

EndSem – 40%

Lab Quiz – 12%

Lab report – 18%

Attendance will be used for clearing boundary cases during grading.



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# History and Introduction: Engineering Materials



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# Materials : “Drivers” of our Society

✓ Rooted in our culture and have influence over virtually every segment of our daily lives –

- ❖ Transportation
- ❖ Housing
- ❖ Clothing
- ❖ Communication
- ❖ Recreation, etc.

✓ Early civilizations have been designated by materials development:

- ❖ Stone Age
- ❖ Bronze Age
- ❖ Iron Age
- ❖ Silicon Age



P. K Kelkar library, IIT Kanpur



Fighter Craft

Image: Ontario sea plane association



Home



Antenna

Image: [www.goes-r.gov](http://www.goes-r.gov)

## World of materials



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# Stone Age

- The term “**Stone Age**” was coined in the late 19th century by the Danish scholar **Christian J. Thomsen**.
- Roughly extended between **15000-2000 BC**.
- Characterized by creation and use of **stone tools**.
- Wood, bones and other materials were also used as tools but have shorter life.



Image: Canadian Anglo-Boer War Museum, Canada



Image: Nubian Museum, Egypt



Image : Wesleyan University, USA



Image: Government Museum, Chennai, India

## Stone Age Tools



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# Bronze Age

- Roughly extend between 3500-500 BC.
- Beginning of **metal working**.
- Copper was mixed with tin, to create a new alloy - **BRONZE**, which was stronger than the other two metals individually.
- Used for tools, weapons, armor, decoration, etc.



Neck collar of Gold

Image: <http://www.britishmuseum.org/>



**Daggers (kind of knife) and Swords**

Image : The Archaeology Gallery at West Stow, England



**Axe Head**

Image: Kenilworth Abbey Barn Museum, UK



**Spartan Armor**

Image: Metropolitan Museum of Art, New York



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# Bronze Age – India

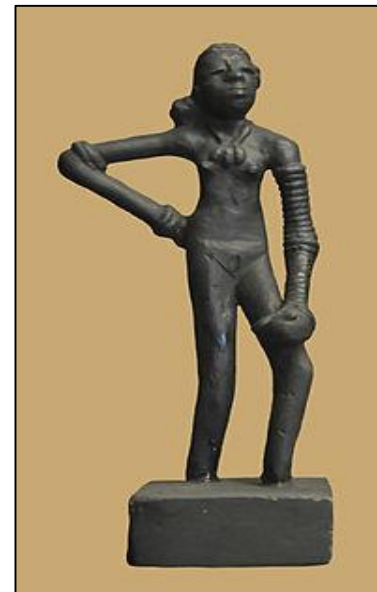
- Begins around 3000 BC.
- Development of Indus valley Civilisation/ Harappa Culture, first ever urban civilisation.

- The famous **Dancing Girl** is a **bronze statuette** (10.5 cm high) casted using the lost wax method and dating around 2500 B.C., from the **Mohenjo-daro site**, Sindh (now in Pakistan) of the Indus Valley Civilization.
- Found by **Ernest Mackay** in 1926.
- Although it is in standing position, it was named "*Dancing Girl*" with an assumption of her profession – 25 bangles in left and 4 bangles in her right hand.



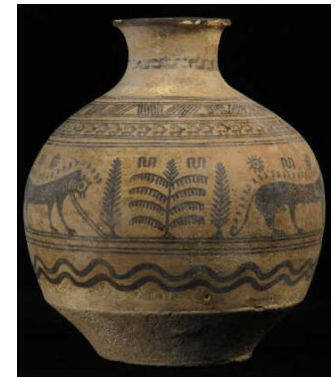
Indus valley civilization

Image: NCERT



*Dancing Girl*

(Image: National Museum, New Delhi, India)



Ceramic Pot, Indus valley

Image: [www.antiques.com](http://www.antiques.com)



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# Iron Age

- It is the **last stage** of the archaeological sequence known as the three-age system (Stone Age, Bronze Age, & Iron Age).
- The Iron Age began about 3000 years ago and **continues till today**. Use of iron and steel has changed drastically the human development.
- Witnessed **industrial revolution**.
- Improved modes of transportation –Automobiles, Railways and aero planes.



Transportation modes



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Image: [www.pinterest.com](http://www.pinterest.com)

# IRON PILLAR OF DELHI

- Iron age in South-Asia begins around 1200 B.C
- **IRON PILLAR OF DELHI** (around 1600 year old) called as “a testament to the skill of ancient Indian blacksmiths”.
- Solid shaft of **wrought iron** (high **phosphorous** content) about 7m tall, 0.4 m diameter weighing over 6,000 kg.
- High resistance to corrosion results from an even layer of crystalline iron hydrogen phosphate hydrate, which serves to protect it from the effects of the local Delhi climate.



Iron Pillar, Qutab Minar Complex, New Delhi, India

In-depth study, book and papers published by Late **Prof. R. Balasubramaniam**, Department of Materials Science and Engineering, IIT Kanpur, [http://www.iitk.ac.in/infocell/Archive/dirnov1/iron\\_pillar.html](http://www.iitk.ac.in/infocell/Archive/dirnov1/iron_pillar.html)



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# World's First Cast Iron Bridge

- Built over the **River Severn** in Shropshire, **England**.
- **First arch bridge in the world** to be made of **Cast Iron**.
- Opened in the year 1781.
- Longest span = 31m



The Iron Bridge, England

Image: Wikipedia



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# The Steel Story

Steel is an **alloy of iron and carbon** (less than 2% by weight) added with **other alloying elements** such as sulphur, phosphorous, manganese, chromium, etc. to achieve variety of properties.

**13<sup>th</sup> Century BC** : Early blacksmiths discovered that iron became harder and stronger when left in charcoal furnaces.

**3<sup>rd</sup> Century BC** : “**Wootz Steel** (Ancient India)”  
The craftsmen of southern India used crucibles to smelt wrought iron with charcoal to produce ‘Wootz’ steel – still admired today.

**Roman Era** : The Romans learned how to temper work-hardened steel to reduce its brittleness

**3<sup>rd</sup> century AD** : Chinese created steel by melting together wrought iron with cast iron



## Modern era in Steel making

- 1855** : Henry **Bessemer**, steel mass production began with Bessemer convertor – air blast injected into molten pig iron (carbon 3.5-4.5%) to reduce its carbon content – suitable for phosphorous free ores.
- 1860** : **Gilchrist-Thomas process** - improvement to the Bessemer process – used limestone to remove phosphorous
- 1865** : **Siemens-Martin/Open-hearth process** - complemented the Bessemer process - melting iron bar or steel scrap with pig iron until carbon content reduced by dilution and oxidation
- 1953** : **Basic oxygen steelmaking** – used oxygen blast instead of air.
- Latest** : **Electric arc furnace** - highly efficient recycler of steel scrap



Steel can be recycled endlessly with no detrimental effects on its properties. All steel created as long ago as 150 years can be recycled and used in new products and applications.





# India's Contribution in Steel making

**Wootz steel**: Born in ancient India

- In early 3<sup>rd</sup> century BC, the craftsmen of southern India used crucibles to smelt wrought iron with charcoal to produce '**Wootz steel**'.
- Wootz steel characterized by a pattern of bands, which are formed by **sheets of micro carbides** within a **tempered martensite** or **pearlite matrix in high carbon steel**, or by **ferrite and pearlite banding in lower carbon steels**.
- It was widely exported (as cakes) and traded throughout ancient Europe and the Arab world, and became particularly famous in the Middle East for making Swords.
- Another sign of its reputation is seen in a **Persian phrase** – to give an "**Indian answer**", means "**a cut with an Indian sword**".
- The 12th century Arab traveler "**Edrisi**" mentioned the word "**Hinduwani**" or '**Indian steel as the best in the world**' then.
- Michael Faraday who contributed to the study of electricity and electromagnetism, also spent 4 years studying the properties of Indian Wootz steel.
- The techniques for its making died out slowly. The research is underway to reproduce it.



**Wootz blade**

Image: Wikipedia



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# Steel lifeline – Rail track

- World has total rail network of about 16 lakh km length.
- **India** has **4<sup>th</sup> longest** railway network (65,000 km) after USA(2.5L), China(1.2L) and Russia(86k).
- **Rail steel** contains carbon(0.6-0.8%), and other alloying elements such as Mn, Si, S, P, Mo, Cr, V to produce hard, wear & corrosion resistant rails.



**Diamond Crossing, Nagpur\***

\*Place where India crosses from East to West and North to South.

*Samjhauta Express*



**International rail track  
(Atari, India - Lahore, Pakistan)**

**(Opened 1914, L = 2.4 km)**  
Scissor Rail track on **World's 2<sup>nd</sup> most  
corrosive environment**



**Pamban Rail Bridge, Rameshwaram, Tamil Nadu**



**Dudhsagar falls track, Goa**

Source: Indian Railways gallery



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# Howrah Bridge

- Howrah Bridge is a **suspension type Balanced Cantilever bridge** over the Hooghly River in Kolkata, West Bengal, India.
- **World's 6<sup>th</sup> longest cantilever bridge (Longest span = 457 m).**  
1<sup>st</sup> - Quebec Bridge (1917), Canada (longest span - 549m span).
- Official name: **Rabindra Setu**, named after Gurudev “**Rabindranath Tagore**” (**first Asian Nobel laureate**).
- Commissioned in 1943.
- Total length - 705m  
Height - 82 m
- **Material – Steel, supplier TATA Steel**
- Consumed about 26,500 tons of steel, no bolts and nuts used - **only Rivets.**

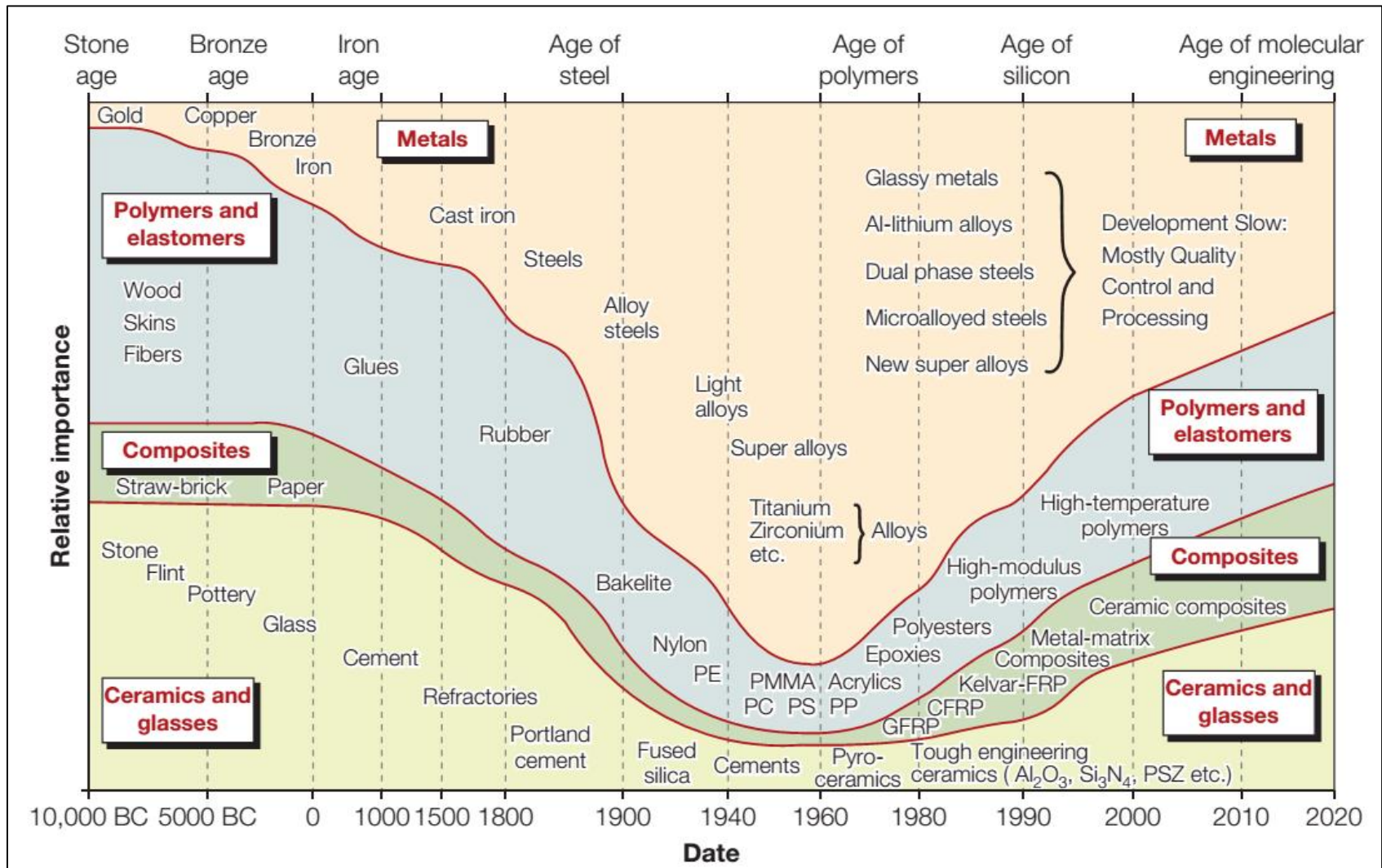


**Howrah Bridge, Kolkata**





# Summary: Material Evolution



Reference: Ashby, Material Selection in Mechanical Design, 4 Ed.



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