How do we choose what material to make the ship out of?

How do we work out how strong to make the ship structure?

How do give ship structures strength?
Materials:

- Steel
- Aluminium
- Composites

Materials - Steel:

- Steel is alloy of iron & carbon
- For shipbuilding usually mild steel with 0.15 to 0.23% carbon and reasonably high manganese content.
Materials - Steel:

Advantages:
- Reasonable cost
- Easily welded with simple techniques & equipment
- Ductility & homogeneity

Disadvantages:
- High weight to strength ratio
- Susceptible to corrosion
Materials - Steel:

- Steel sections are rolled from ingots
- Standard section types utilised to reduce work, (also channel section)

Materials – High Tensile Steel:

- HTS have higher strength than mild steels.
- Used in more highly stressed regions of large tankers, container ships & bulk carriers.
- Use allows thickness reductions & hence weight reduction (larger unit fabrications possible) – however also leads to larger deflections.
- Increased material cost
Materials - Aluminium:

Advantages:
- Lighter than mild steel
  Aluminium = 2.723 tonnes/m$^3$
  Steel = 7.84 tonnes/m$^3$
- Non-magnetic
- High resistance to corrosion (care required with dissimilar metals, e.g. steel)

Disadvantages:
- High initial cost – approx 8 to 10 times price of steel per tonne
- Large vessels (> 120m) require very large plate thicknesses, e.g. 25mm plate
- Low melting point – fire protection required
Materials - Aluminium:

Good applications:
• Superstructure on steel vessels to reduce total displacement & lower centre of gravity.
• High speed vessels
• Deadweight/lightship ratio is low
e.g. High speed ferries, passenger liners, military vessels

Materials - Aluminium:

Mined ore = bauxite
Bauxite purified to obtain pure aluminium oxide (alumina)
Alumina reduced to metallic aluminium
Alloys added & metal cast in billet or slabs
Plates are rolled from cast slabs
Sections are produced by extrusion – forcing billet of hot material through a die of required shape.
Materials - Composites:

Composites are composed of stiff fibres embedded in a flexible, tough resin matrix.
The fibres carry the bulk of the loads whereas the resin protects the fibre, provides watertight integrity and allows load transfer.
Composite skin may be single skin (monolithic) or sandwich.
Laminate may be specified by stacking sequence (orientation of the warp direction for each ply) and ply list (fibre types)

Materials - Composites:

Typical fibre types:
- Carbon
- Aramid (kevlar)
- Glass

Typical fibre forms:
- chopped strand mat
- Woven
- Uni-directional
- Multiaxial
Materials - Composites:

Typical resins:
• Polyester
• Vinylester
• Epoxy

Typical cores:
• Foam
• Balsa
• Honeycomb
• Aluminium

Advantages:
• Stronger & stiffer than metals on density basis
• Highly corrosion resistant
• Excellent formability (intricate shapes)

Disadvantages:
• High cost

Conventional GRP 5-20% heavier than aluminium but advanced carbon sandwich 40% lighter than aluminium.
Testing of Materials:

Metals are tested to ensure strength, ductility & toughness are suitable for required function.

Stress is the force acting on a unit area of material.

Strain is deforming of material due to stress.

Tests:

- **Tensile test** – axial pull, minimum yield stress, ultimate tensile stress, elongation.
- **Impact test** – Charpy V notch, ability to withstand fracture under shock loading.

Stresses experienced by ships:

In still water
Stresses experienced by ships:

In waves
Stresses experienced by ships:

Stress, $\sigma$, at any point in a beam is given by:

$$\sigma = \frac{M}{I} y$$

$M$ = applied bending moment
$y$ = distance from point considered neutral axis
$I = 2^{nd}$ moment of area of beam cross section

Ship as a beam:
Ship as a beam:

Hull can be considered a box shaped girder.
Neutral axis generally closer to keel, since bottom shell thicker than deck (needs to resist water/slamming pressure as well as longitudinal bending).
Bending stress greater in mid section of ship – maximum scantlings at 40% length amidships.
Uppermost flange often referred to as strength deck.

Other loads:

Transverse stresses:
Racking – deck moving laterally relative to bottom structure.
Torsion – twisting moment.

Local stresses:
Slamming – impact loads in waves
Panting – pressure fluctuations
Local loads - towing
Scantling Determination:

- Structural calculations
- Finite element analysis
- Classification rules

Construction drawings:
How do we choose what material to make the ship out of?

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Further reading:

Recap/Reflect