Eng. 6002
Ship Structures 1

LECTURE 2: SHIP STRUCTURAL COMPONENTS

6.3 Ship Structure

Longitudinal Structural Components

Starting from the keel to the deck:

- **Keel**

  - Large center-plane girder

  - Runs longitudinally along the bottom of the ship

- **Longitudinals**

  - Girders running parallel to the keel along the bottom

  - It provides longitudinal strength

Longitudinal Structural Components (cont'd)

- **Stringer**

  - Girders running along the sides of the ship

  - Typically smaller than a longitudinal

  - Provides longitudinal strength

- **Deck Girder**

  - Longitudinal member of the deck frame (deck longitudinal)

….*Primary role* of longitudinal members :

Resist the longitudinal bending stress due to sagging and hogging

Transverse Structural Components

•***Primary role*** **of transverse members : to resist the hydrostatic loads**

Starting from the keel to the deck:

- **Floor**

  - Deep frame running from the keel to the turn of the bilge

- **Frame**

  - A transverse member running from keel to deck

  - Resists hydrostatic pressure, waves, impact, etc.

  - Frames may be attached to the floors (Frame would be the part above the floor)

- **Deck Beams**

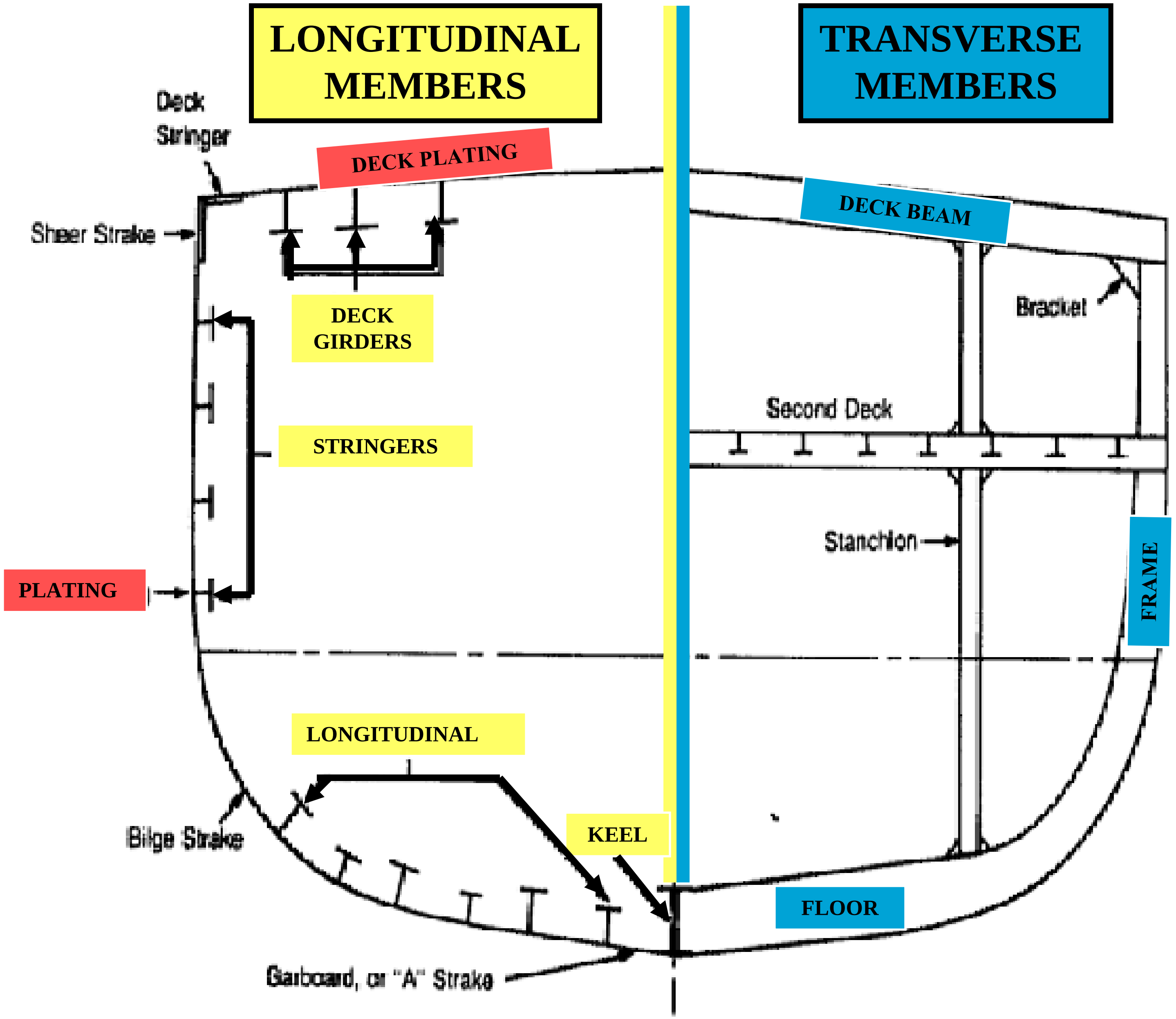
  - Transverse member of the deck frame

- **Plating**

  - Thin pieces closing in the top, bottom and side of structure

  - Contributes significantly to longitudinal hull strength

  - Resists the hydrostatic pressure load (or side impact)


LONGITUDINAL MEMBERS
TRANSVERSE MEMBERS
Deck Stringer
DECK PLATING
Sheer Strake
DECK GIRDERS
STRINGERS
PLATING
LONGITUDINAL
Bilge Strake
KEEL
Garboard, or "A" Strake
DECK BEAM
Bracket
Second Deck
Stanchion
FRAME
FLOOR

The ship's strength can be increased by:

- **Adding more members**
- **increasing the size & thickness of plating and structural pieces**

All this will increase cost, reduce space utilization, and allow less mission equipment to be added

Optimization

- Longitudinal Framing System
- Transverse Framing System
- Combination of Framing System

Longitudinal Framing System

Primary role* of longitudinal members : *to resist the longitudinal bending stress due to sagging and hogging

- **A typical wave length in the ocean is 300 ft. Ships of this length or greater are likely to experience considerable longitudinal bending stress**

- **Ship that are longer than 300ft (long ship) tend to have a greater number of longitudinal members than transverse members**

Longitudinal Framing System :

- Longitudinals spaced frequently but shallower

- Frames are spaced widely

Transverse Framing System

•***Primary role* of transverse members : to resist the hydrostatic loads**

- **Ships shorter than 300ft and submersibles**

•**Transverse Framing System:**

- Longitudinals are spaced widely but deep.

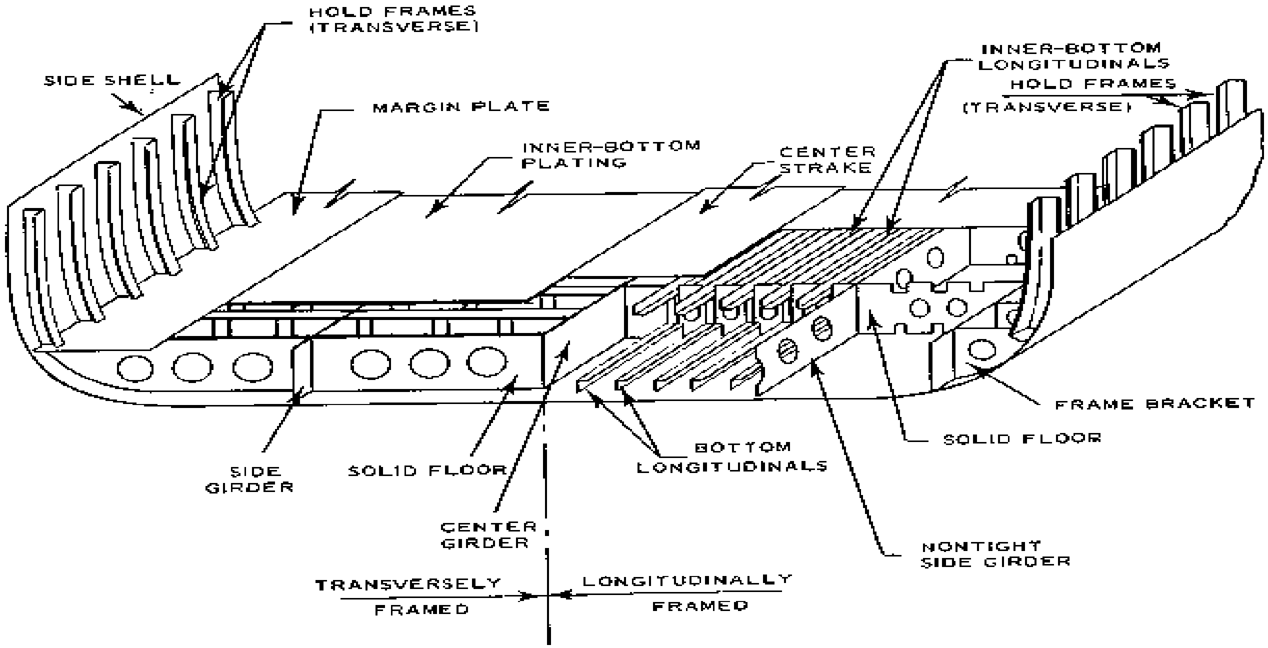
- Frames are spaced closely and continuously

•**Transverse members: frame, floor, deck beam, platings**

Combined Framing System

Optimization of the structural arrangement for the expected loading to minimize the cost

- **Combination of longitudinal and transverse framing system**
- **Typical combination :**
  - **Longitudinals and stringers with shallow frame**
  - **Deep frame every 3rd or 4th frame**



igure 5–25. Double-bottom construction with transverse framing illustrated on the lefthand side and longitudinal framing on he righthand side. (From Taggart 1980.)

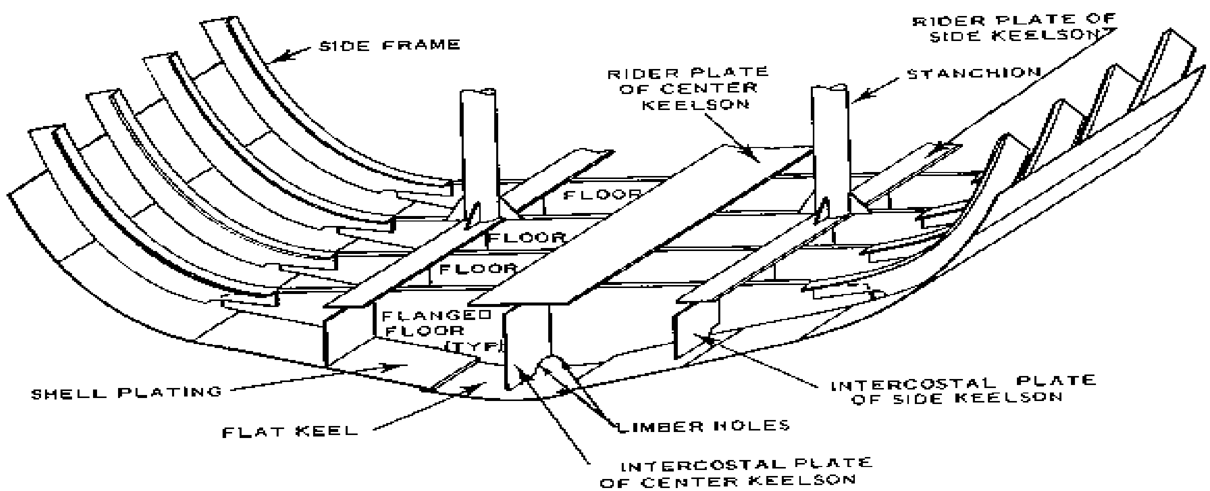


Figure 5–26. Single-bottom construction. (From Taggart 1980.)

Double Bottoms

Two watertight bottoms with a void space

- **Resists:**

  - Upward pressure

  - bending stresses

  - bottom damage by grounding and underwater shock

- **The double bottom provides a space for storing:**

  - fuel oil

  - ballast water & fresh water

- **Smooth inner bottom which make it easier to arrange cargo & equipment and clean the cargo hold**

Watertight Bulkheads

Large bulkhead which splits the the hull into separate sections

- **Primary role**

  - *Stiffening the ship*
  - *Reducing the effect of damage*

- **The careful positioning the bulkheads allows the ship to fulfill the damage stability criteria**
- **The bulkheads are often stiffened by steel members in the vertical and horizontal directions**

Eng. 6002 Ship Structures 1
Hull Girder Response Analysis

LECTURE 3: LOAD, SHEAR FORCE, BENDING MOMENT

Overview

- For the purpose of analysis, the primary level of response of a ship is modelled as a hollow, thin-wall box beam known as the hull girder
- Can use simple beam theory, where:
  - Longitudinal position, loads and deflections have a single value at any cross section
  - The hull girder remains elastic with small deflections, and the strain due to bending varies linearly over the cross section (about a neutral axis)
  - Static equilibrium applies
  - Horizontal and vertical bending of hull girder may be superimposed

Load, Shear and Bending

- Overall static equilibrium requires that the total buoyancy force equals the weight of the ship, and l.c.b coincides with l.c.g

$$\rho g \int_0^L a(x)\,dx = g \int_0^L m(x)\,dx = g\Delta$$

where:

$a(x)$ = immersed cross-sectional area

$m(x)$ = mass distribution

ρ = density of seawater

g = gravitational acceleration

Δ = displacement

Load, Shear and Bending

- Similarly, moment equilibrium requires that:

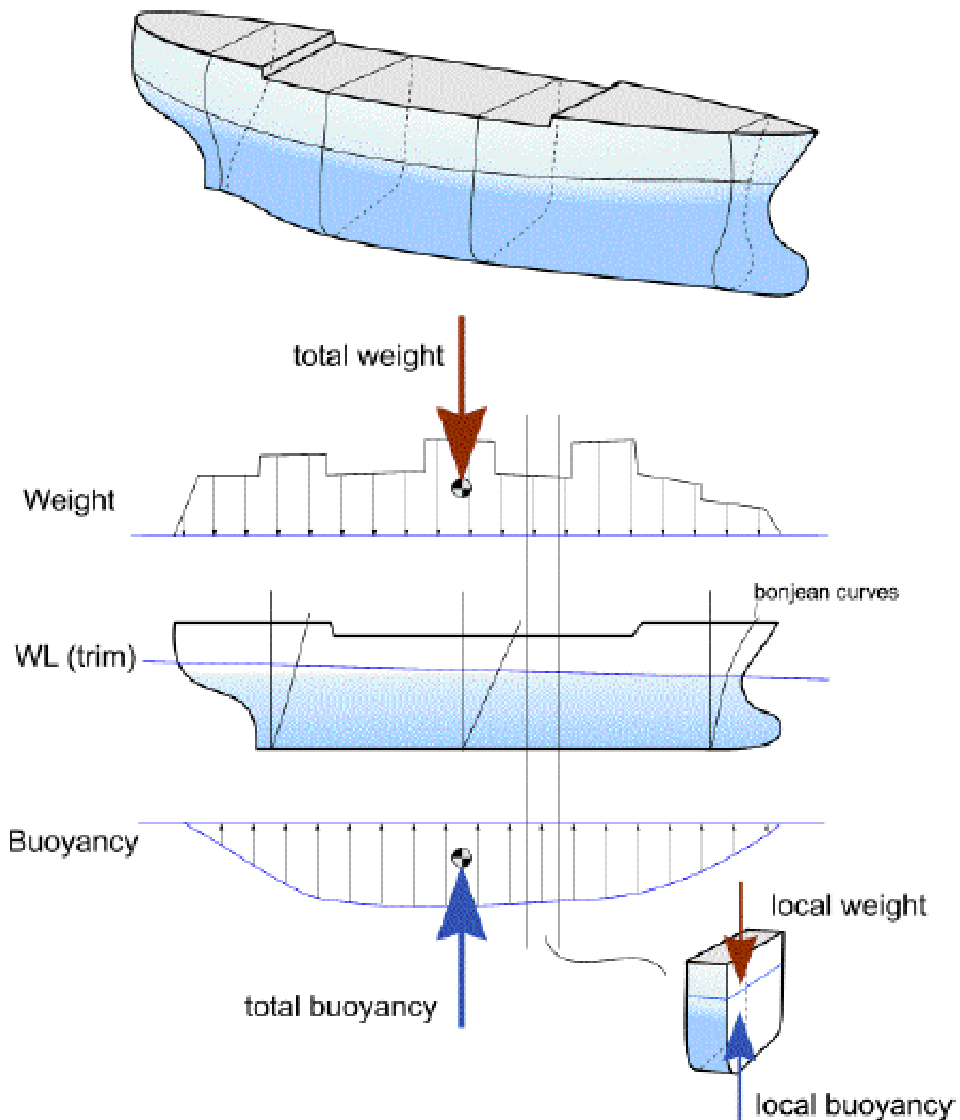
$$\rho g \int_0^L a(x) x \, dx = g \int_0^L m(x) \, x dx = g \Delta l_G$$

where :

l_G = distance from origin to l.c.g

Distribution of Weights

- The weight will not equal the buoyancy at each location along the ship.
- The weights are a combination of lightship and cargo weights (more or less fixed).
- The buoyancy forces are determined by the shape of the hull and the position of the vessel in the water (draft and trim).
- The net buoyancy will adjust itself until it exactly counteracts the net weight force.
- Local segments of the vessel may have more or less weight than the local buoyancy. The difference will be made up by a transfer of shear forces along the vessel.



Beam Theory

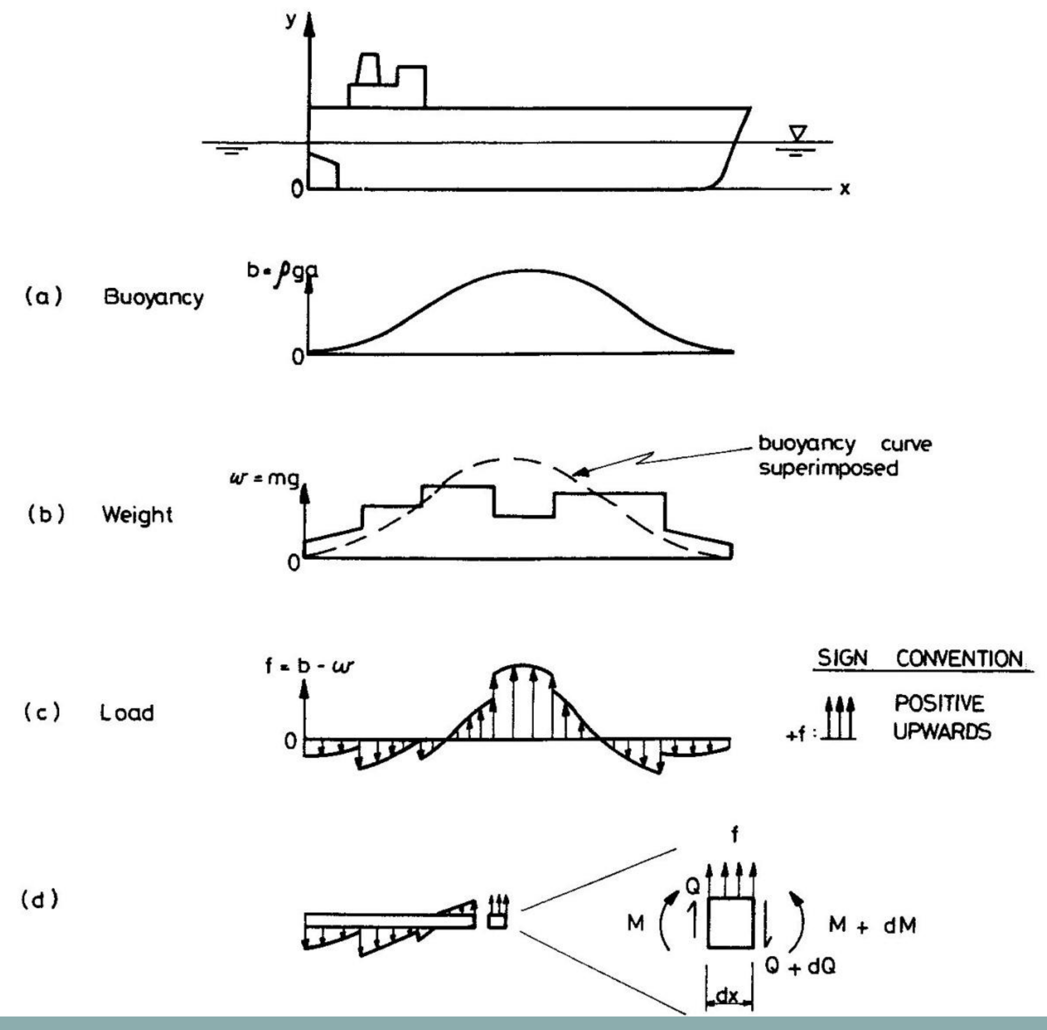
- The governing equation for the bending moment, *M(x)*, is:

$$\frac{d^2M}{dx^2} = f(x)$$

where $f(x)$ is the loading on the beam

- For a ship f(x) is a net distributed force, given by the resultant of the weight and buoyancy forces : f(x) = b(x) – w(x)

Figure 3.1 (a-d), Hughes



Beam Theory Cont.

- To solve for *M(x)* we first need the transverse shear force, *Q(x)*.
- Summing the moments about a differential element gives:

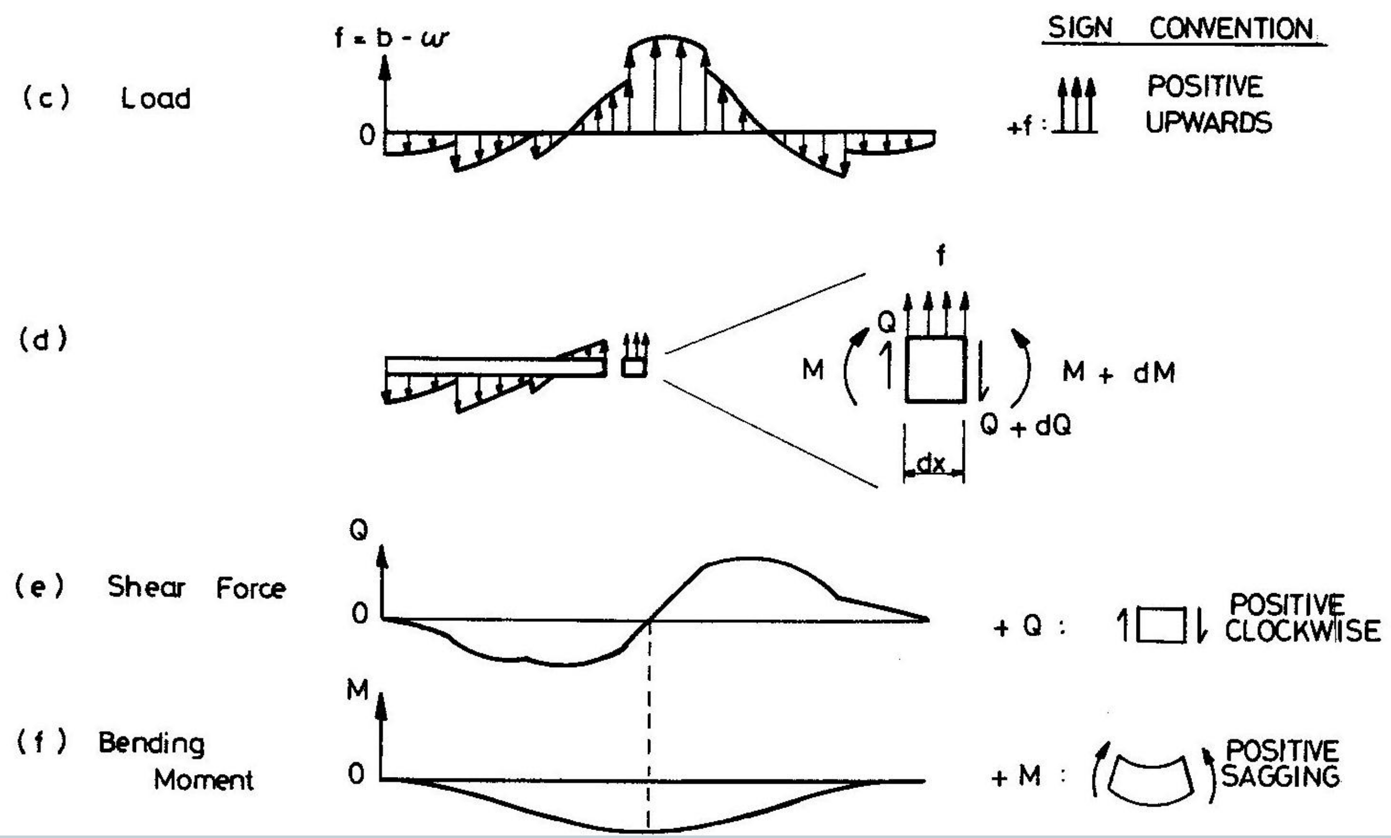
$$Q(x) = \int_0^x f(x)dx$$

$$M(x) = \int_0^x Q(x)\,dx$$

Sign Conventions

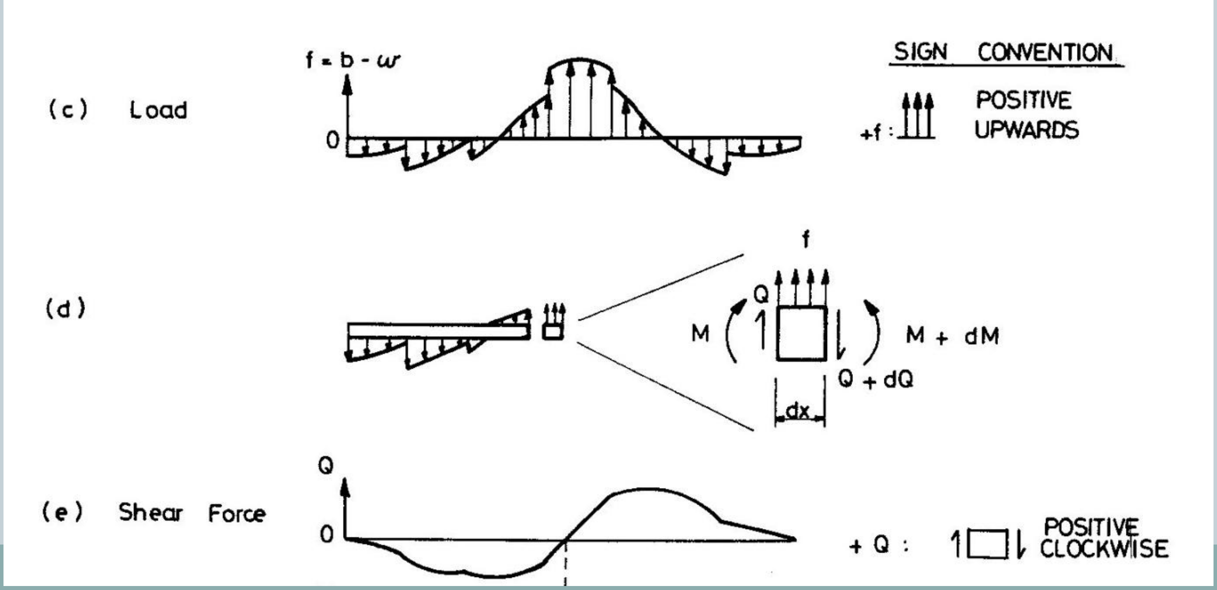
- Positive shear causes clockwise rotation of an element
- Positive bending moment corresponds to concave upwards, or "sagging"
- Negative bending moment corresponds to concave downwards, or "hogging"

Shear Force and Bending Moment Curves



Shear Force and Bending Moment Curves

- Features;
  - Zero load corresponds to max (or min) shear force
  - In general the shear force is zero near amidships and has peaks near quarter points



Shear Force and Bending Moment Curves

- Features;
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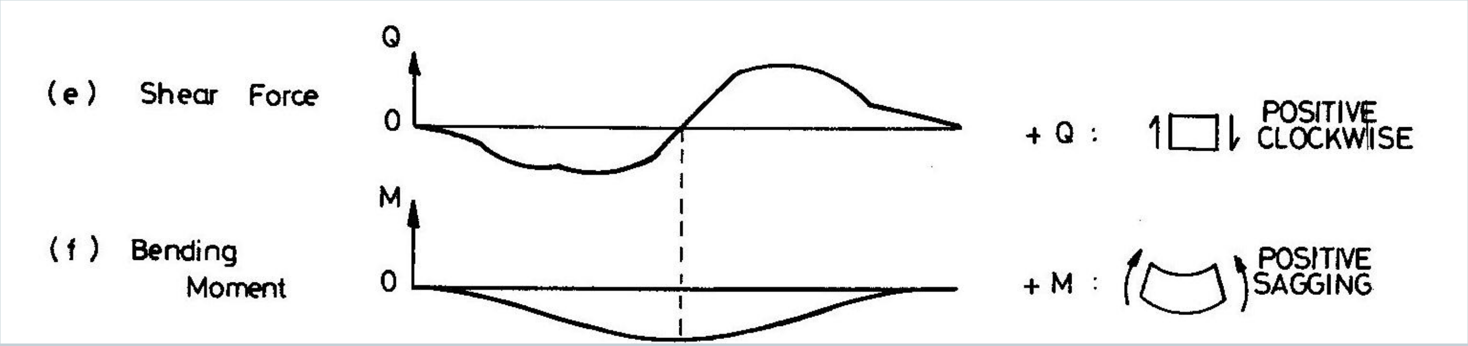


Still Water vs Wave Loading

- There are two buoyancy forces to consider:
  - Still water: static quantity that is a function of hull shape.
  - Wave: dynamic and probabilistic.
- The buoyancy distribution in waves is calculated separately and superimposed on the still water buoyancy force

Still Water vs Wave Loading cont.

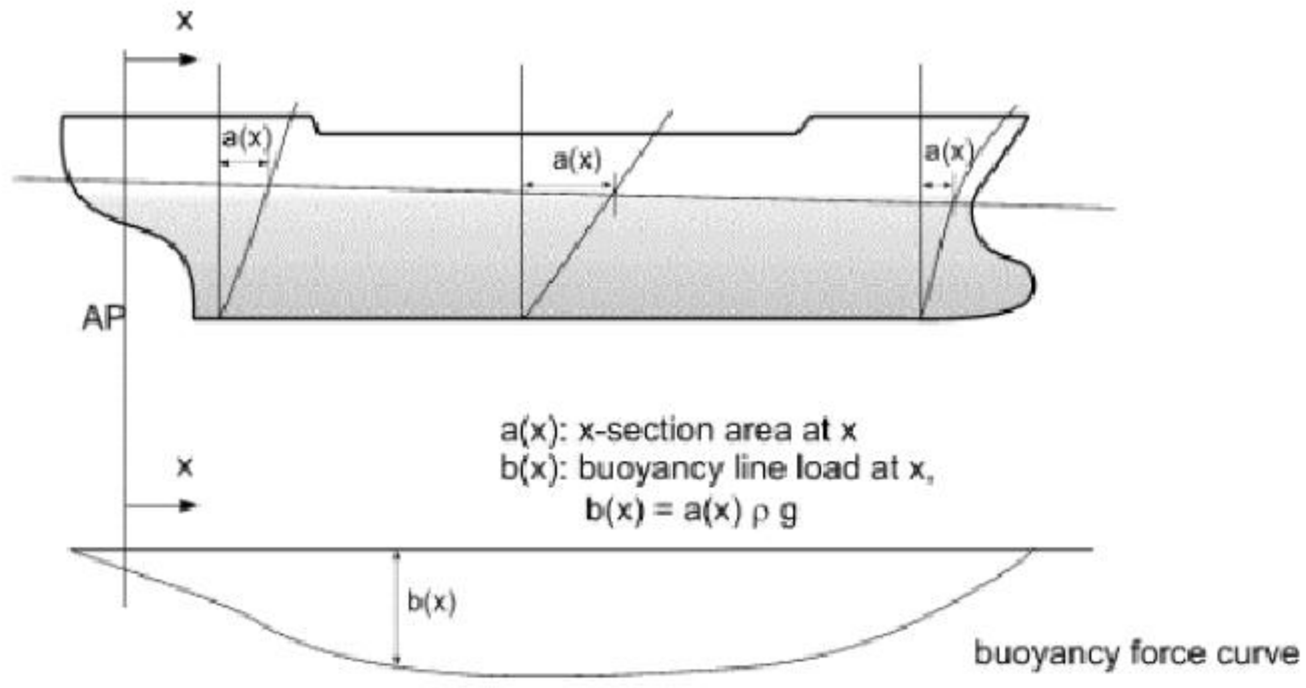
- The still water buoyancy distribution is determined from the static and moment equilibrium equations (described previously in this lecture)
- So we need to know the mass distribution $m(x)$ (or at least the displacement and location of l.c.g)

Bonjean Curves

- The local buoyancy per metre can be determined from the cross-sectional area of the hull at discrete locations
- The cross-sectional area depends on the local draft and is found using “bonjean” curves

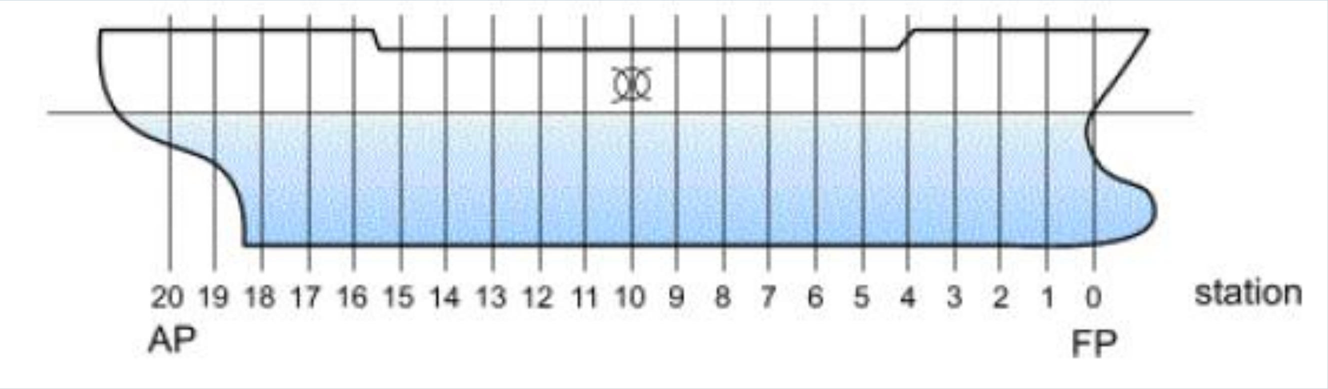
Bonjean Curves cont.

$$\underbrace{(Hull\ Form)}_{bonjean} + \underbrace{(draft + trim)}_{waterline} \rightarrow (buoyancy\ forces)$$



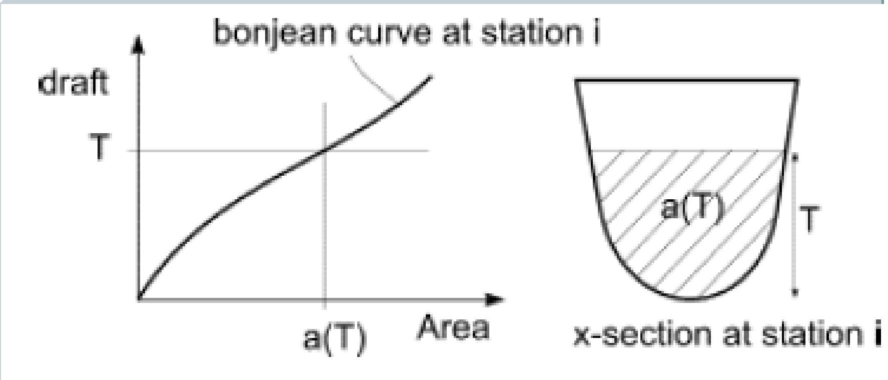
Bonjean Curves cont.

- There is one bonjean curve for each station. There are 21 stations from FP to AP, so we can divide the LBP into 20 segments

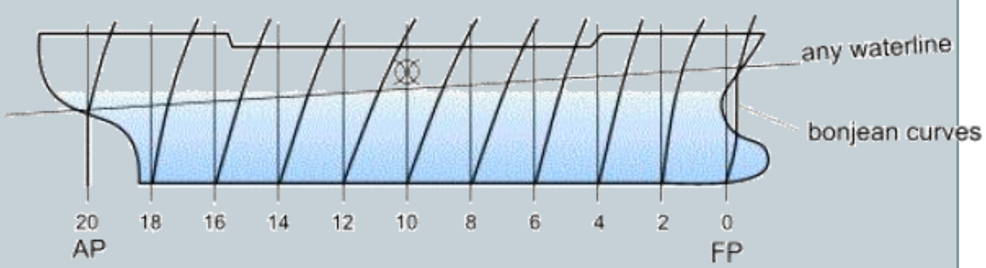


Bonjean Curves cont.

- At each station a curve of the cross-sectional area is drawn



- Bonjean curves are shown on the profile of the vessel and we use them to determine the buoyancy distribution at an waterline



Bonjean Curves cont.

- The total displacement at a given draft/trim is found by summing the contribution of each segment

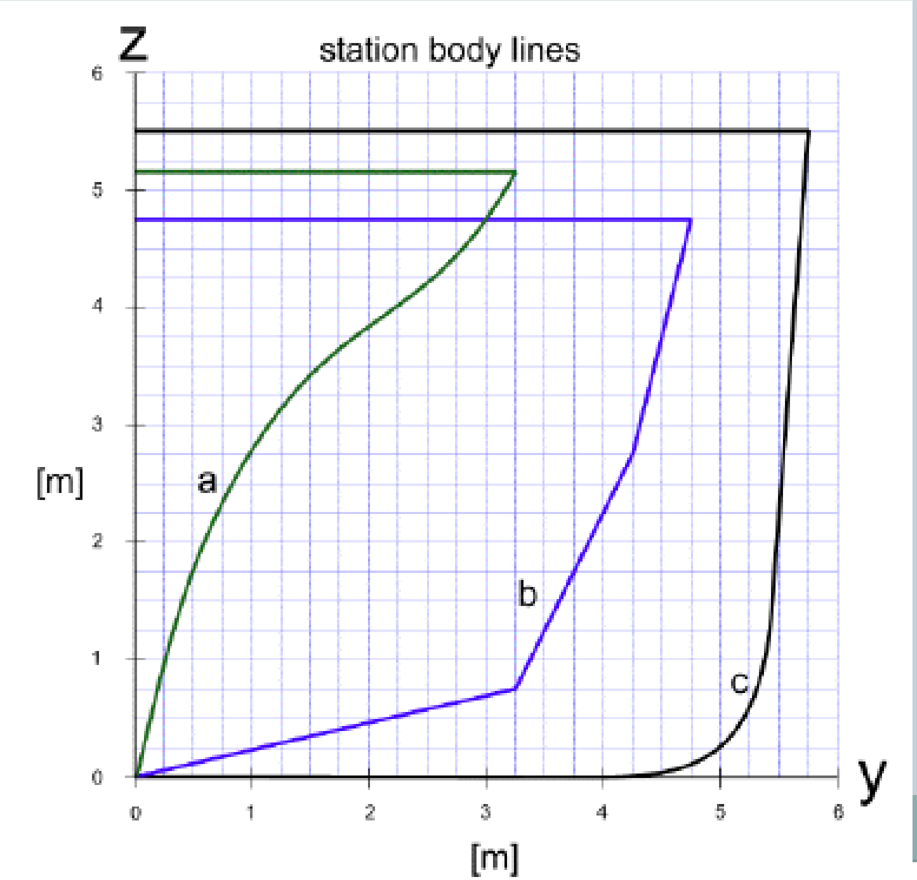
$$\nabla = \sum_{i=0}^{20} \left\{ a_i \left(T_i \right) \cdot \frac{LBP}{20} \right\} [\mathrm{m}^3]$$

- The buoyant line load (used for calculating the buoyant force at each station) is then given by Δ_i

$$\Delta_i = \nabla_i \cdot \rho \cdot g$$

Assignment #1

- For the three station profiles shown below, draw the bonjean curves



Next Class

- Estimation of weight distribution
- Calculation of still water bending moment