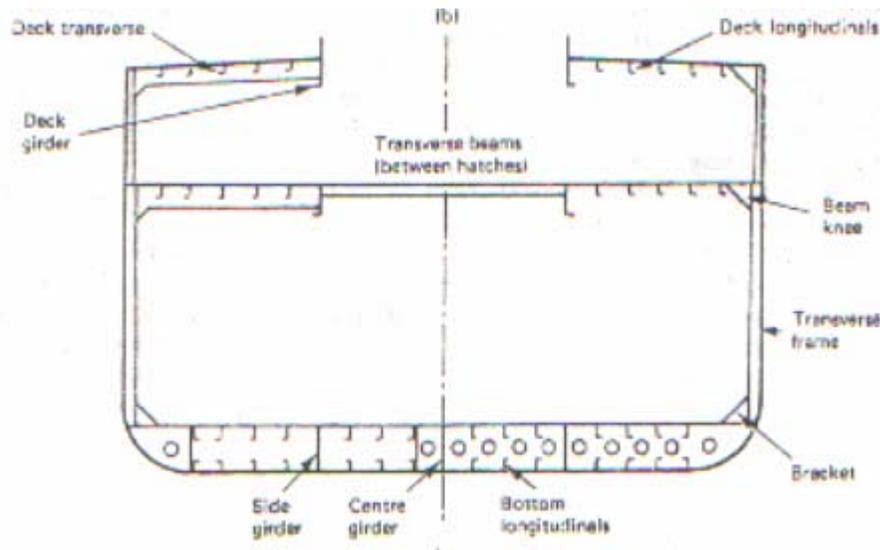


## 1- Ship Types and Features

Several basic ship types are considered. The particular features of appearance, construction, layout, size, etc., will be examined for the following ship types:

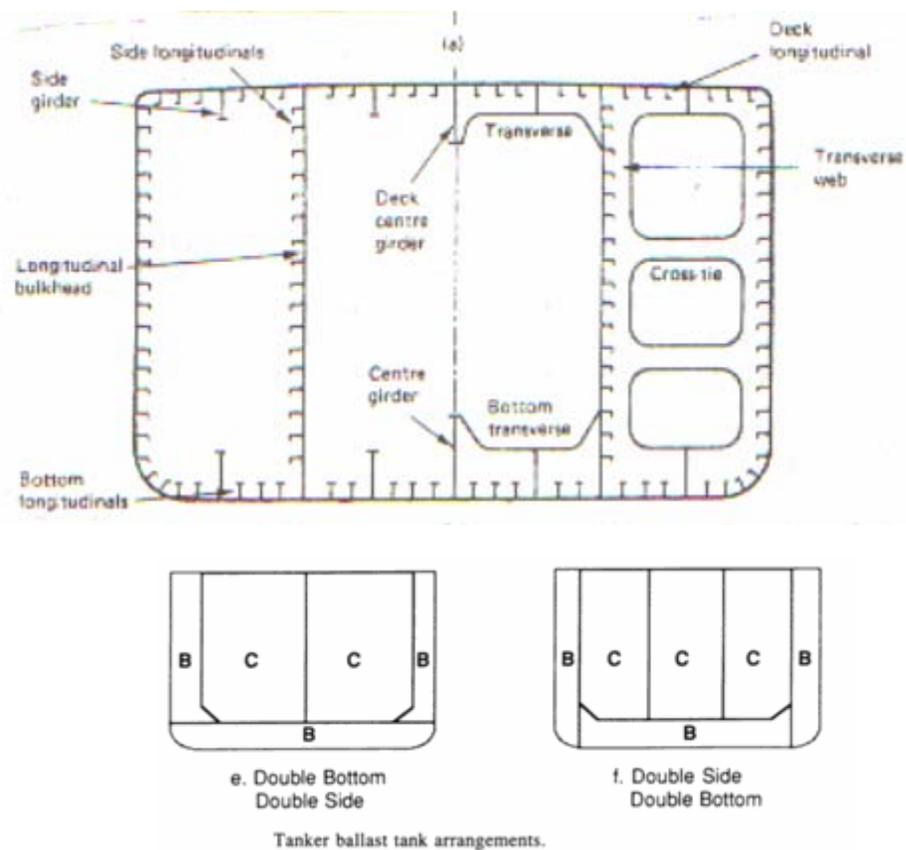
- (1) General cargo ships.
- (2) Tankers.
- (3) Bulk carriers.
- (4) Container ships.
- (5) Passenger ships.

### General cargo ships



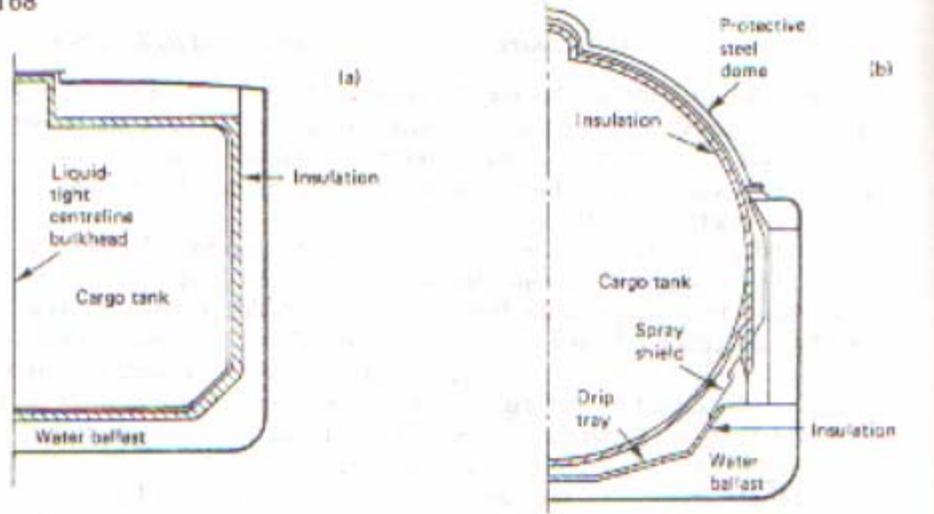
1. The general cargo consists of as large a clear open cargo-carrying space as possible, together with the facilities required for loading and unloading the cargo.
2. Access to the cargo storage areas or holds is provided by openings in the deck called hatches. Hatches are made as large as strength considerations will allow to reduce horizontal movement of cargo within the ship.
3. Hatch covers of wood or steel, as in most modern ships, are used to close the hatch openings when the ship is at sea. The hatch covers are made watertight and lie upon coamings around the hatch which are set some distance from the upper or weather deck to reduce the risk of flooding in heavy seas.
4. One or more separate decks are fitted in the cargo holds and are known as tween decks. Greater flexibility in loading and unloading, together with cargo segregation and improved stability, are possible using the tween deck spaces.
5. Various combinations of derricks, winches and deck cranes are used for the
6. Handling of cargo.
7. The accommodation and machinery spaces are usually located with one hold between them and the aft peak bulkhead.

## Tankers

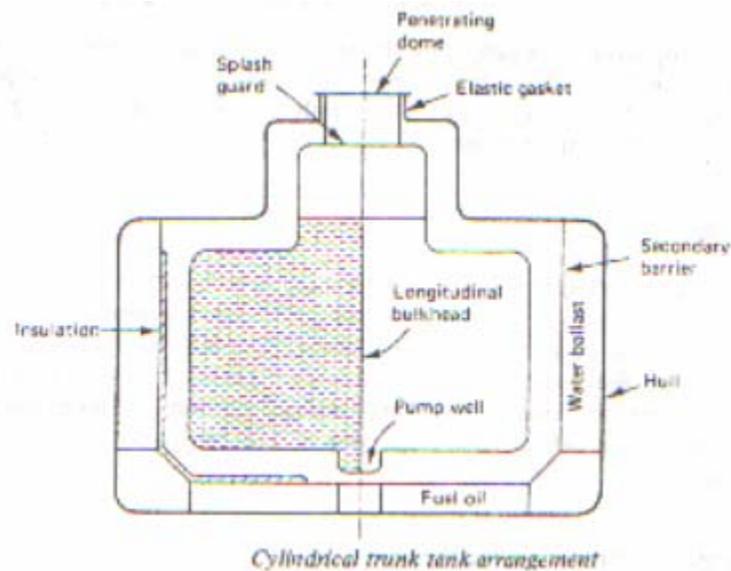


1. The tanker is used to carry bulk liquid cargoes, the most common type being the oil tanker.
2. The oil tanker has the cargo-carrying section of the vessel split up into individual tanks by longitudinal and transverse bulkheads.
3. Double bottom or/and double sides or double hull is fitted in the cargo-carrying section of an oil tanker.
4. A pair of wing tanks are created by longitudinal bulkheads. These wing tanks help reduce the free surface effect.
5. Large amounts of piping are to be seen on the deck running from the pump rooms to the discharge manifolds positioned at midships, port and starboard.

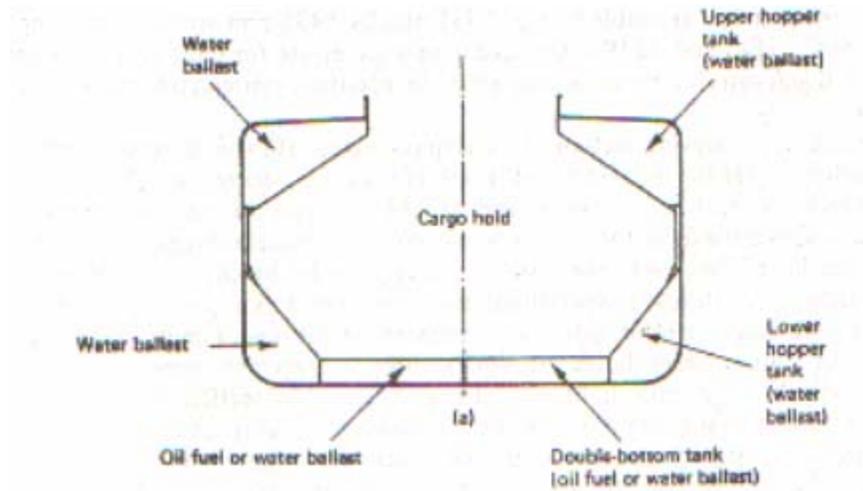
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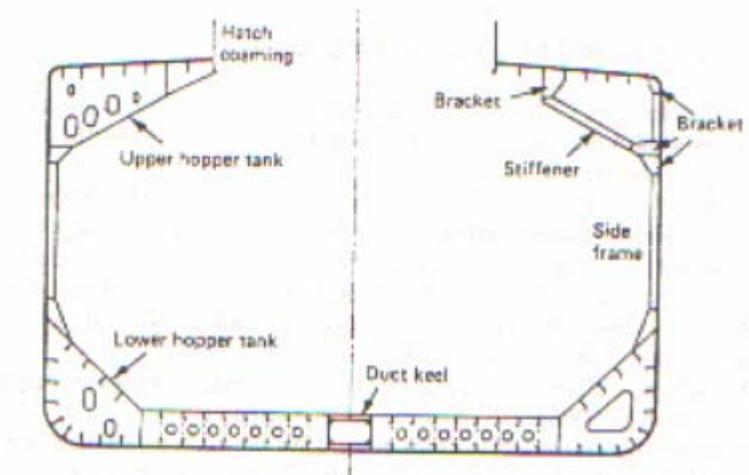
6. LNG tankers carry methane and other paraffin products obtained as byproduct of petroleum drilling operations. The gas is carried at atmospheric pressure and temperatures as low as  $-164^{\circ}\text{C}$  in tanks of special materials, which can accept the low temperature. The tanks used may be prismatic, cylindrical or spherical in shape and self-supporting or of membrane construction.
7. LPG tankers carry propane, butane, propylene, etc., which are extracted from natural gas. The gases are carried either fully pressurized, part pressurized part refrigerated or fully refrigerated. The fully pressurized tank operates at 18 bar and ambient temperature, the fully refrigerated tank at 0.25 bar and  $-50^{\circ}\text{C}$ . Tank shapes are prismatic, spherical or cylindrical. Low temperature steels may be used on the hull where it acts as a secondary barrier.



## Bulk/Ore carriers

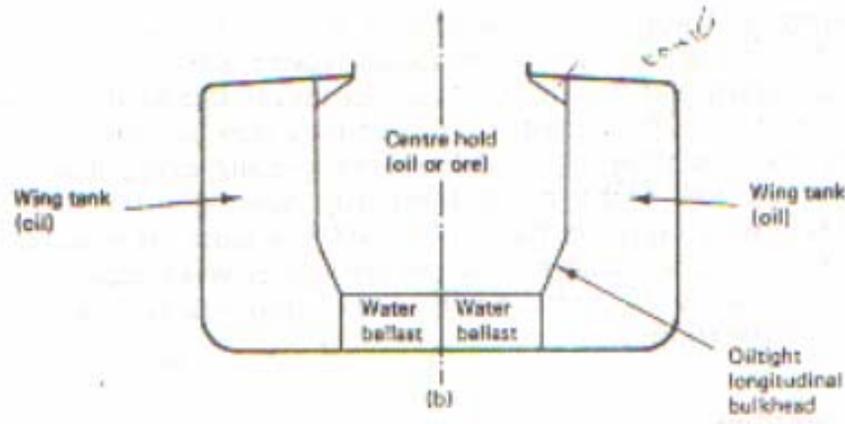


1. Bulk carriers are single-deck vessels, which transport single-commodity cargoes
2. such as grain, sugar and ores in bulk.



3. The general-purpose bulk carrier, in which usually the central hold section only is used for cargo
4. The partitioned tanks which surround it are used for ballast purposes either on ballast voyages or; in the case of the saddle tanks, to raise the ship's center of gravity when a low density cargo is carried.
5. Some of the double-bottom tanks may be used for fuel oil and fresh water.

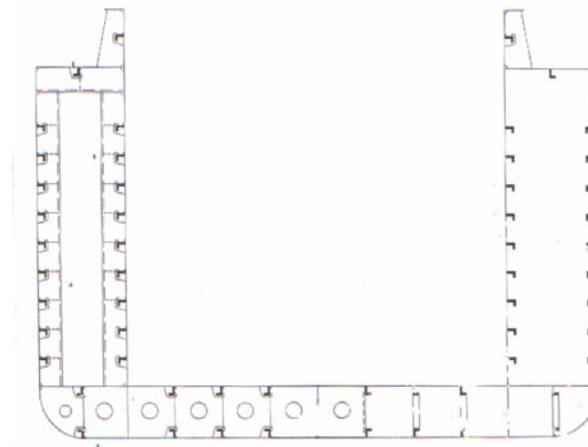
6. The saddle tanks also serve to shape the upper region of the cargo hold and trim the cargo. Large hatchways are a feature of bulk carriers, since they reduce cargo-handling



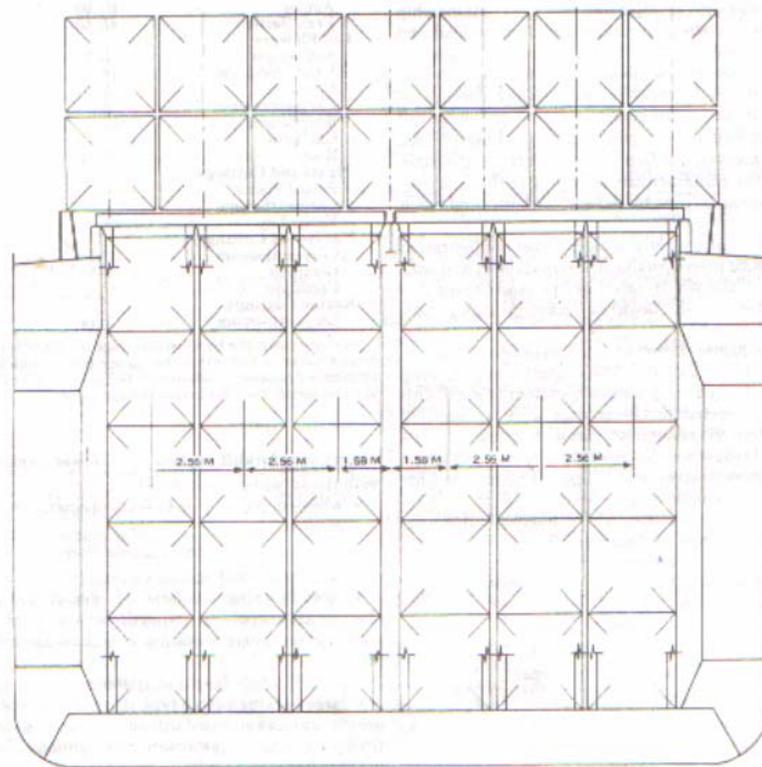
time during loading and unloading.

1. An ore carrier has two longitudinal bulkheads, which divide the cargo section into wing tanks port and starboard, and the center hold, which is used for ore.
2. On loaded voyages the ore is carried in the central hold, and the high double bottom serves to raise the center of gravity of this very dense cargo.
3. Two longitudinal bulkheads are employed to divide the ship into center and wing tanks which are used for the carriage of oil cargoes.
4. When ore is carried, only the center tank section is used for cargo.
5. A double bottom is fitted beneath the center tank but is used only for water ballast.
6. The structure is significantly stronger, since the bulkheads must be oil tight and the double bottom must withstand the high-density ore load.
7. Large hatches are a feature of all bulk carriers, to facilitate rapid simple cargo handling.
8. A large proportion of bulk carriers do not carry cargo-handling equipment, because they trade between special terminals which have particular equipment for loading and unloading bulk commodities.

### Container ships



1. A container is a re-usable box of 2435 mm by 2435 mm section, with lengths of 6055, 9125 and 12 190 mm.
2. Containers are in use for most general cargoes, and liquid-carrying versions also exist. In addition, refrigerated models are in use.
3. The cargo-carrying section of the ship is divided into several holds which have hatch openings the full width and length of the hold.
4. Cargo handling consists only of vertical movement of the cargo in the hold.
5. Containers can also be stacked on the hatch covers where a low-density cargo is carried.
6. The various cargo holds are separated by a deep web-framed structure to provide the ship with transverse strength
7. The ship section outboard of the containers on each side is a box-like arrangement of wing tanks, which provides longitudinal strength to the structure. These wing tanks may be utilized for water ballast.
8. A double bottom is also fitted which adds to the longitudinal strength and provides additional ballast spacer

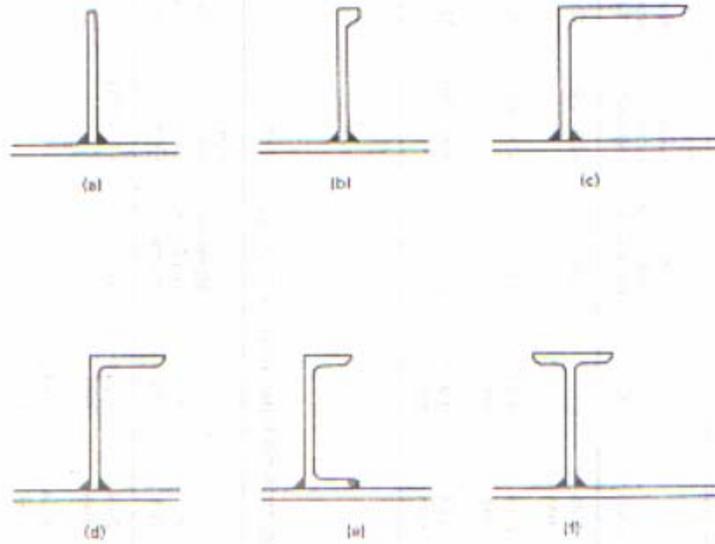


### Passenger ships

1. The passenger traveling in such a ship pays for, and expects, a superior standard of accommodation and leisure facilities.
2. Large amounts of superstructure are therefore an essential feature of passenger ships.
3. Several tiers of decks are filled with large open lounges, ballrooms, swimming pools and promenade areas.
4. Stabilizers are fitted for reduce rolling and bow thrust devices are employed for improved maneuverability.

## 2. Shipbuilding Steel and Materials

### Shipbuilding Steel



Standard steel sections: (a) flat plate; (b) offset bulb plate; (c) equal angle; (d) unequal angle; (e) channel; (f) tee

The steel used in shipbuilding is mainly mild steel with 0.15-0.23% carbon content. Five grades of mild steel (A-E) are used, manufactured, inspected, and tested under certain conditions. Finished steel is stamped by the classification societies.

High tensile steel is developed to have higher toughness, ductility, weldability, and strength. This is developed by addition element such as vanadium, chromium, nickel, and Niobium.

PROPERTIES AND COMPOSITION OF SOME MILD STEELS

	C (%)	Mn (%)	Si (%)	S (%)	P (%)	Al (%)	Minimum yield stress (N/mm <sup>2</sup> )	Ultimate tensile stress (N/mm <sup>2</sup> )	Minimum elongation (%)
LR 'A' mild steel	0.23 max.	2.5 x C min.	0.50 max.	0.05 max.	0.05 max.	—	230	400–490	22
LR 'D' mild steel	0.21 max.	0.70–1.40	0.10–0.50	0.04 max.	0.04 max.	0.015 min.	235	400–490	22
LR 'E' mild steel	0.18 max.	0.70–1.50	0.10–0.50	0.04 max.	0.04 max.	0.015 min.	235	400–490	22

PROPERTIES AND COMPOSITION OF SOME HIGHER TENSILE STEELS

	C (%)	Mn (%)	Si (%)	S (%)	P (%)	Al (%)	Minimum yield stress (N/mm <sup>2</sup> )	Ultimate tensile stress (N/mm <sup>2</sup> )	Minimum elongation (%)
LR AH32	0.18 max.	0.70–1.60	0.50 max.	0.04 max.	0.04 max.	0.015 min.	315	440–590	22
LR AH36	0.18 max.	0.70–1.60	0.50 max.	0.04 max.	0.04 max.	0.015 min.	355	490–620	21
LR EH36	0.18 max.	0.70–1.60	0.10–0.50	0.04 max.	0.04 max.	0.015 min.	355	490–620	21

### Aluminum Alloys

Aluminum use in shipbuilding has increased due to the lighter weight (1/3 weight of steel). This reduction of weight in the upper structure of the ship results in an improve of the ship stability. Aluminum has a good resistance to corrosion. The main disadvantage of Aluminum is the high cost.

Aluminum section are formed by extrusion. A special insulating arrangement is used when joining steel to Aluminum.



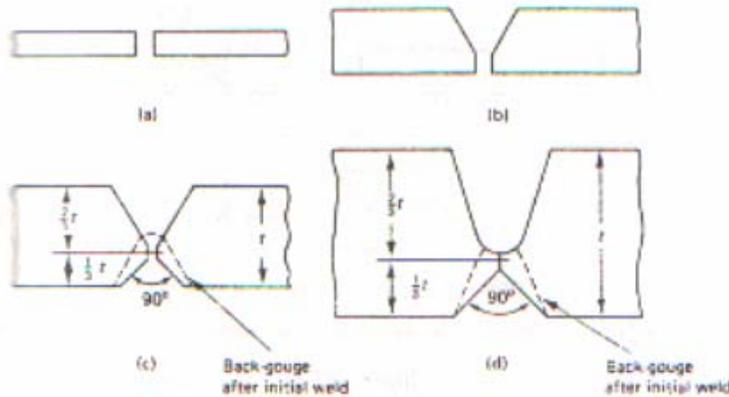
Aluminium alloy sections

PROPERTIES AND COMPOSITION OF ALUMINIUM ALLOY CONSTRUCTIONAL MATERIALS

	Cu (%)	Mg (%)	Si (%)	Fe (%)	Mn (%)	Zn (%)	Cr (%)	Ti (%)	Al (%)	Minimum proof stress (N/mm <sup>2</sup> )	Minimum ultimate tensile strength (N/mm <sup>2</sup> )
AL 1 (LR) Plates and sections	0.10 max.	3.5- 5.6	0.5 max.	0.5 max.	1.0 max.	0.2 max.	0.35 max.	0.2 max.	Rem.	125	260
AL 2 (LR) Plates and sections	0.10 max.	0.4- 1.4	0.6- 1.6	0.5 max.	0.2- 1.0	0.2 max.	0.35 max.	0.2 max.	Rem.	195	260
AL 3 (LR) Rivets	0.10 max.	3.0- 3.9	0.5 max.	0.5 max.	0.6 max.	0.2 max.	0.35 max.	0.2 max.	Rem.	90	220
AL 4 (LR) Rivets	0.10 max.	0.4- 1.4	0.6- 1.6	0.5 max.	0.2- 1.0	0.2 max.	0.35 max.	0.2 max.	Rem.	120	190

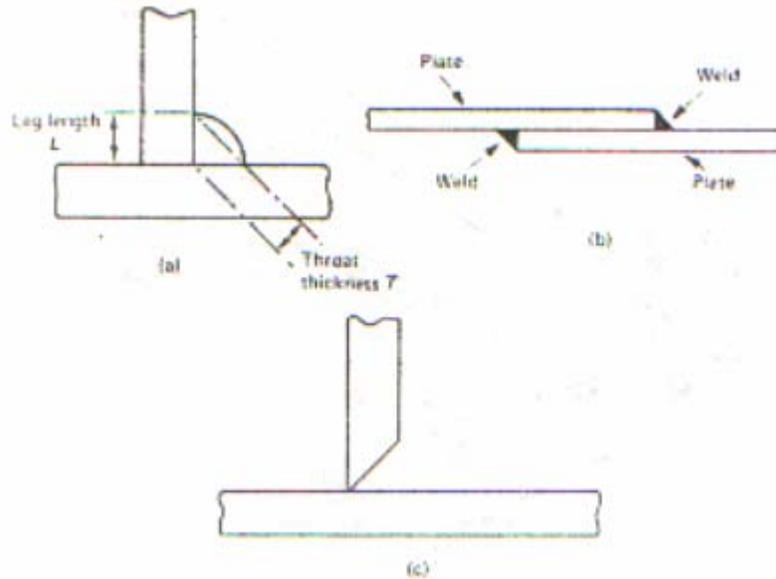
### Types of Weld

Butt weld: the strongest type against tension: square edge for less than 6 mm, V type for (6-20 mm), and a U-weld results in less welding material but more expensive edge preparation.



Butt weld preparations: (a) square butt joint; (b) single-V butt joint; (c) double-V butt joint; (d) double-U butt joint

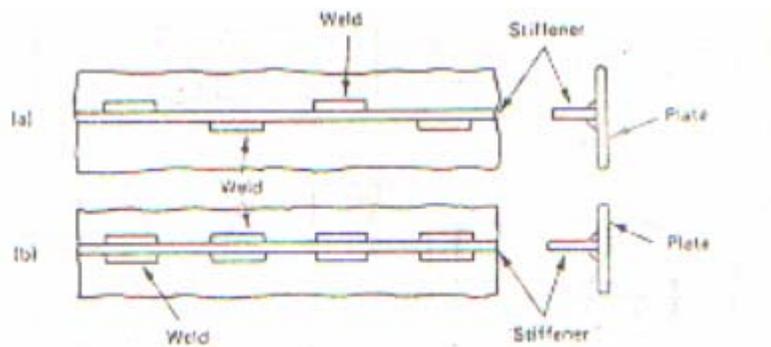
Fillet welding is used for right angle and lapped plates, the throat thickness,  $T$ , is 70% of the leg length,  $L$ . Full penetration is used for special strength requirements.



Fillet welds: (a) fillet weld; (b) lap weld; (c) fillet weld with full penetration preparation

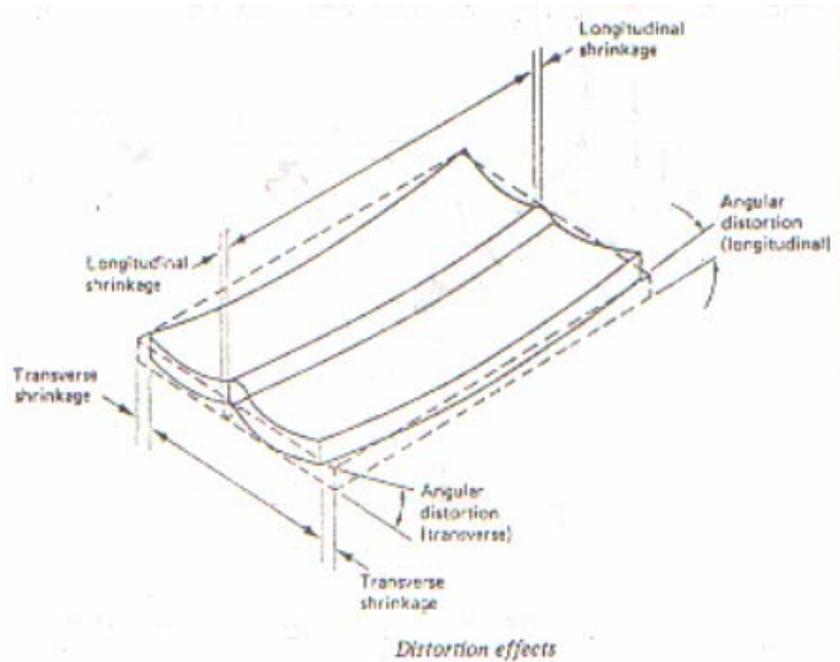
### Weld Distortion

Intermediate and chain welding is used to save material and reduce weight. Continuous weld is used only for oiltightness and important strength connection.



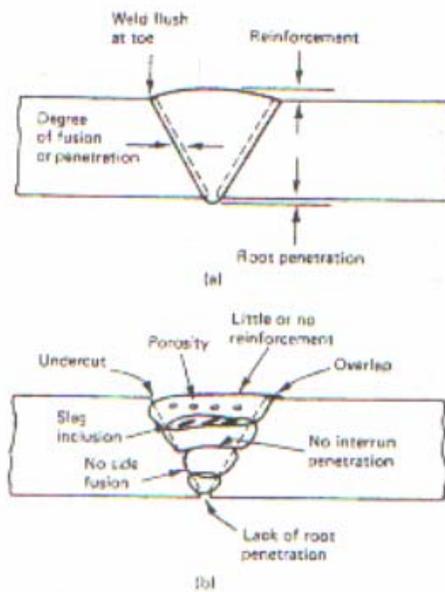
Non-continuous fillet welds: (a) intermittent welding; (b) chain welding

Welding distortion occurs due to heating of areas of plating then cooling of these areas. Distortion also occurs due to the difference between deposited weld metal and parent metal.



**Weld Faults:**

faults occur due to bad workmanship, wrong processing, wrong material used, etc. In bad weld, the absence of reinforcement and root penetration is a result of incorrect procedure or bad workmanship. Overlap is infused metal over the parent metal, undercut is caused by a high welding current. Porosity is caused by gases trapped in the weld. Slag inclusion is a result of inadequate cleaning between weld runs. Poor fusion is a result of incorrect voltage or current setting. A bad weld can start a point for crack.

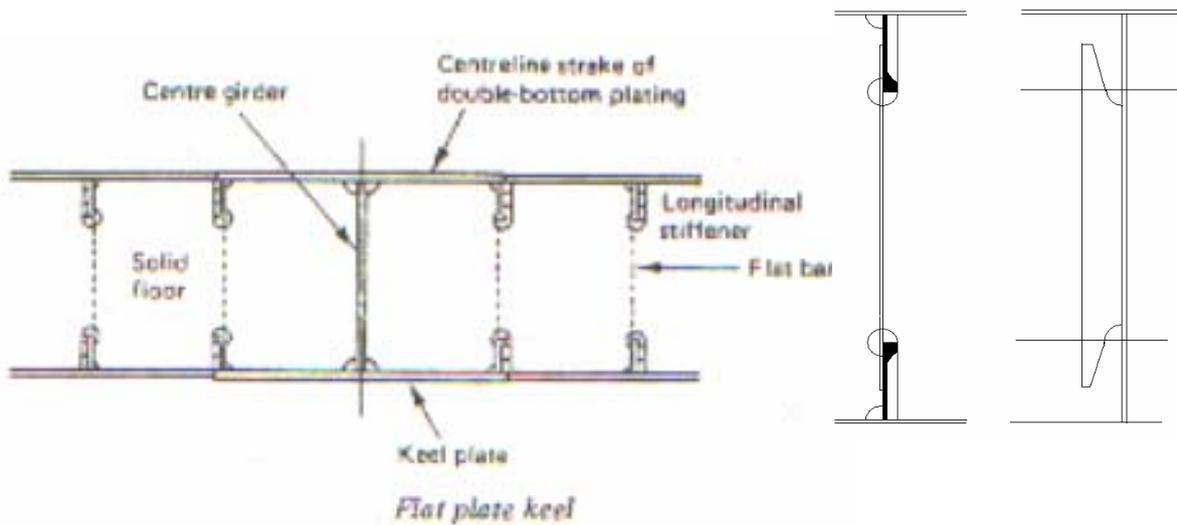


Examples of welds: (a) a good weld; (b) a bad weld

### 3. Bottom Construction

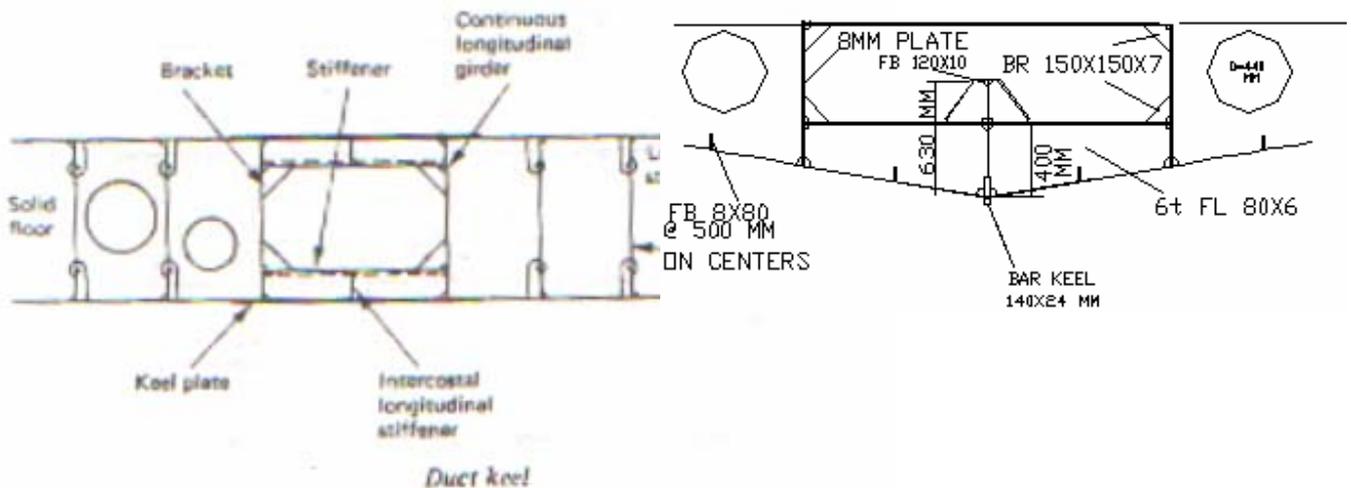
#### Keel

The keel runs along the centerline of the bottom plating of the ship and for the majority of merchant ships is of a flat plate construction. At right angles to the flat plate keel, running along the ship's centerline from the fore peak to the aft peak bulkhead, is a watertight longitudinal division known as the center girder or vertical keel. This provides considerable strength to the structure and



resistance to bending.

Some double bottoms have a duct keel fitted along the centerline. No duct keel is necessary in the machinery space or aft of it. The construction of the duct keel uses two longitudinal girders spaced not more than 2.0 m apart. Stiffeners are fitted to shell and bottom plating at alternate frame spaces and are bracketed to the longitudinal girders. The keel plate and the tank top above the duct keel must have their scantlings increased to compensate for the reduced strength of the transverse floors.



#### Double-bottom structure

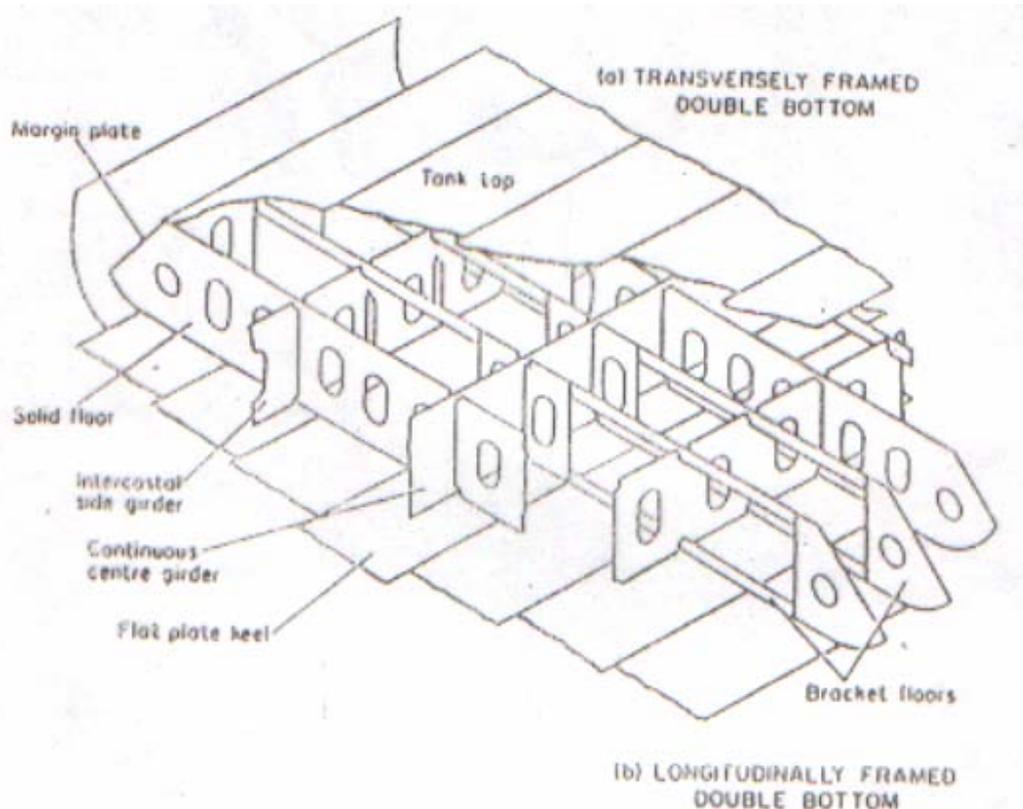
The minimum depth is determined by rule requirements for the size of vessel but the actual depth is sometimes increased in places to suit double-bottom tank capacities. The structure is made up of

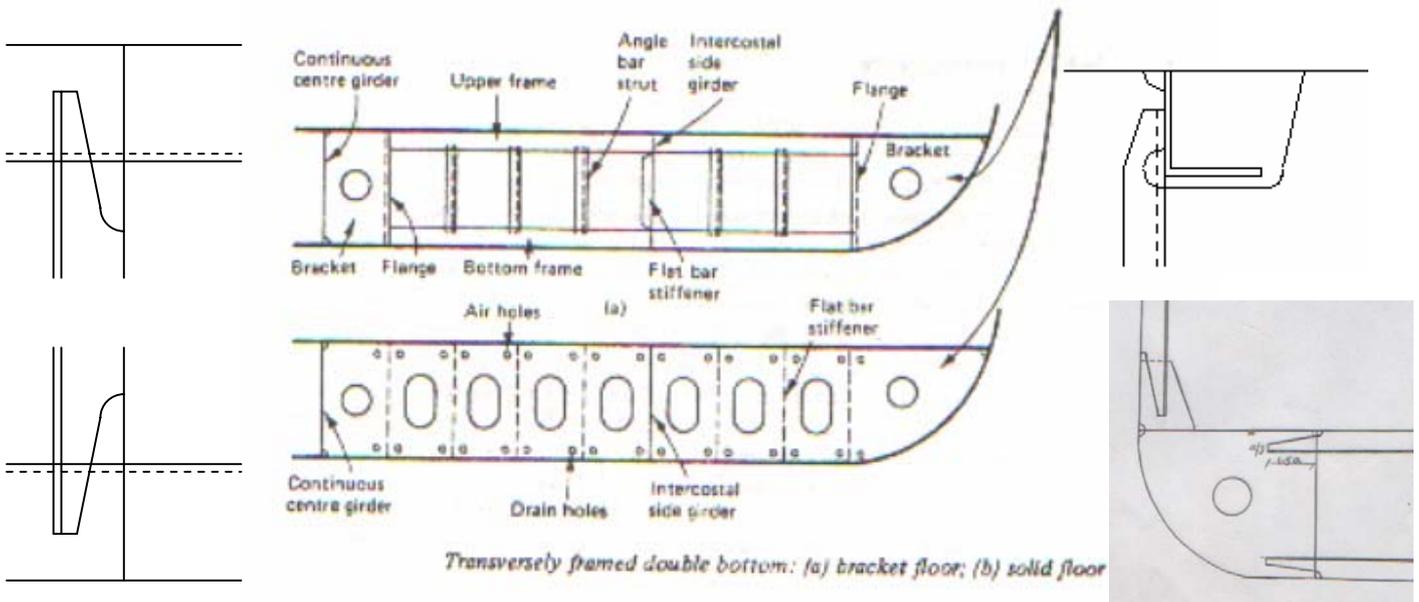
vertical floors which may be watertight, solid or of bracket construction. The floor structure is continuous from the center girder to the side shell and supports the inner bottom shell. Side girders are fitted in the longitudinal direction, their number depending on the width of the ship. These side girders are broken either side of the floors and are therefore termed intercostal girders.

Watertight or oiltight floors are fitted beneath the main bulkheads and are also used to subdivide the double-bottom space into tanks for various liquids. Solid plate floors of non-watertight construction, usually lightened by manholes, are positioned in other places as required to stiffen the structure. Between solid plate floors, bracket floors are fitted. Bracket floors consist of plate brackets attached to the center girder and the side shell with bulb plate stiffeners running between. The stiffeners are supported by angle bar struts at intervals and any side girders which are present in the structure. The arrangement of flooring will be determined by the type of framing system adopted, which may be either transverse or longitudinal.

### Transversely framed double bottom

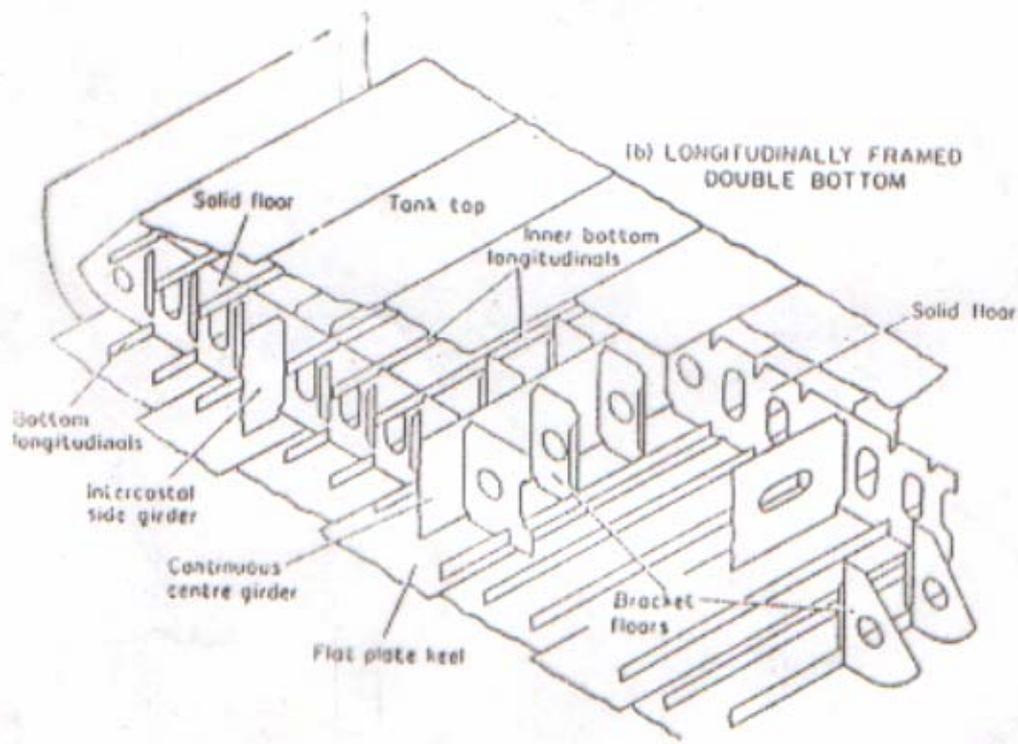
When transversely framed, the double-bottom structure consists of solid plate floors and bracket floors with transverse frames. The bracket floor is fitted between the widely spaced solid floors. It consists of transverse bulb angle sections stiffening the shell and inner bottom plating. Vertical support is provided by brackets at the side shell and center girder, any side girders and intermediate struts. The number of intercostal side girders fitted is determined by classification society rules.

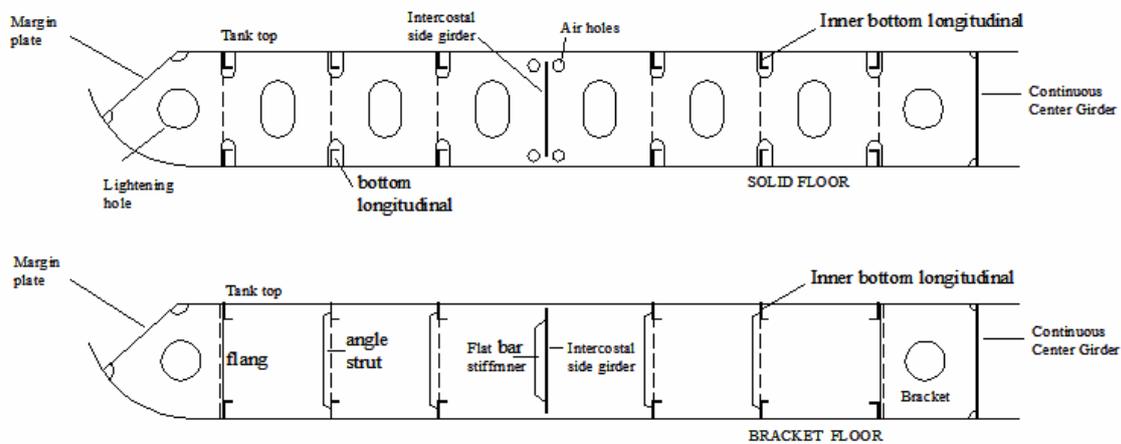




**Longitudinally framed double bottom**

This is the system favored as a result of tests and it provides adequate resistance to distortion on ships of 120 m in length or greater. Offset bulb plates are used as longitudinal stiffeners on the shell and inner bottom plating, at intervals of about 1 m. Solid floors provide support at transverse bulkheads and at intervals not exceeding 3.8 m along the length of the ship. Brackets are fitted at the center girder and side shell at intermediate frame spaces between solid floors. These brackets





Longitudinal framed double bottom construction

are flanged at the free edge and extend to the first longitudinal. Channel bar or angle bar struts are provided to give support at intervals of not more than 2.5 m where solid floors are widely spaced. Intercostal side girders are again fitted, their number depending upon classification society rules.

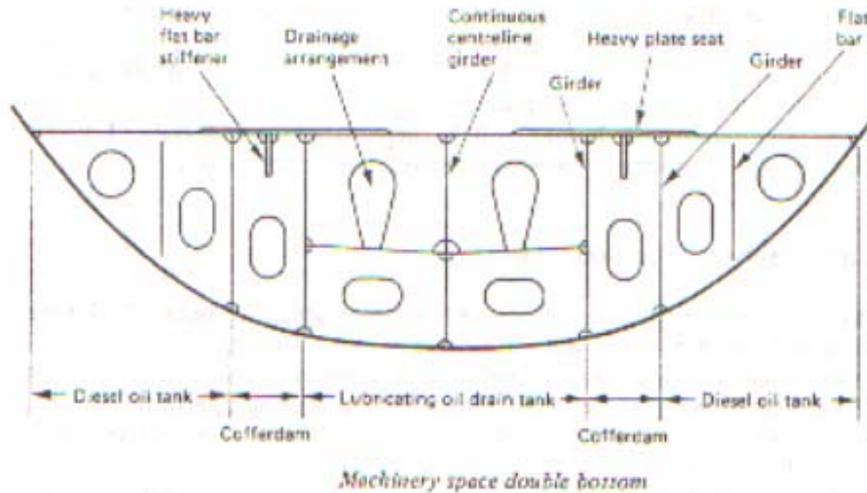
When the longitudinals (stiffeners, frames) run longitudinally effectively continuous through transverse bulkheads, they contribute the section modulus of the hull girder and thus assist in resisting the longitudinal bending of the ship's hull. They also greatly increase the critical compressive buckling strength of the plating to which they are attached. ABS Rules provide for reduction of the required thickness of deck and bottom plating when longitudinally framed. For oil tankers, bulk carriers, general cargo vessels, containerships, and Great Lakes ore carriers, longitudinal framing is generally adopted, at least for the strength deck plating and bottom shell. An exception is made at the ends of the vessel, where the advantages of longitudinal framing disappear and where transverse framing is simpler to build.

In cargo ships and refrigerated cargo vessels, they interfere with cargo stowage and with the joiner work in passenger spaces in passenger vessels. Also, in passenger ships, the longitudinals interfere with running engineering service systems, such as wiring, ventilation, and piping. These supply systems generally run fore-and-aft over the passageways, and longitudinal framing interferes with the transverse branches to the various rooms and spaces being serviced. A practical solution for modern cargo ships is, to frame the bottom shell, inner bottom and strength deck longitudinally utilizing transverse floors every third frame.

### Machinery space double bottom

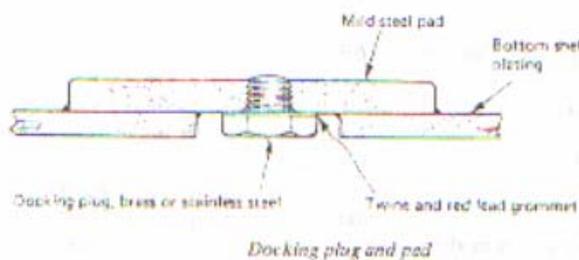
There are solid plate floors at every frame space under the main engine. Additional side girders are fitted outboard of the main engine seating, as required. The double-bottom height is usually increased to provide fuel oil, lubricating oil and fresh water tanks of suitable capacities. Shaft alignment also requires an increase in the double-bottom height or a raised seating. Continuity of strength is ensured and maintained by gradually sloping the tank top height and internal structure to the required position. Additional support and stiffening is necessary for the main engines, boilers,

etc., to provide a vibration-resistant solid platform capable of supporting the concentrated loads. On slow-speed diesel-engine ships, the tank top plating is increased to 40 mm thick or thereabouts in way of the engine bedplate. This is achieved by using a special insert plate which is the length of the engine including the thrust block in size. Additional heavy girders are also fitted under this plate and in other positions under heavy machinery as required. Plating and girder material in the machinery spaces is of increased scantlings in the order of 10%.



**Double-bottom tanks**

Access to the double-bottom tanks is usually by manholes cut in the tank top. These manholes are suitably jointed and bolted to be completely watertight when not in use. Docking plugs are fitted in all double-bottom tanks and are a means of completely draining these tanks for inspection in drydock. Air pipes are fitted to all double-bottom tanks to release the air when filling. Sounding pipes are also fitted to enable the tanks to be sounded and their capacity determined. All double-bottom tanks are tested on completion by the maximum service pressure head of water or an equivalent air test.

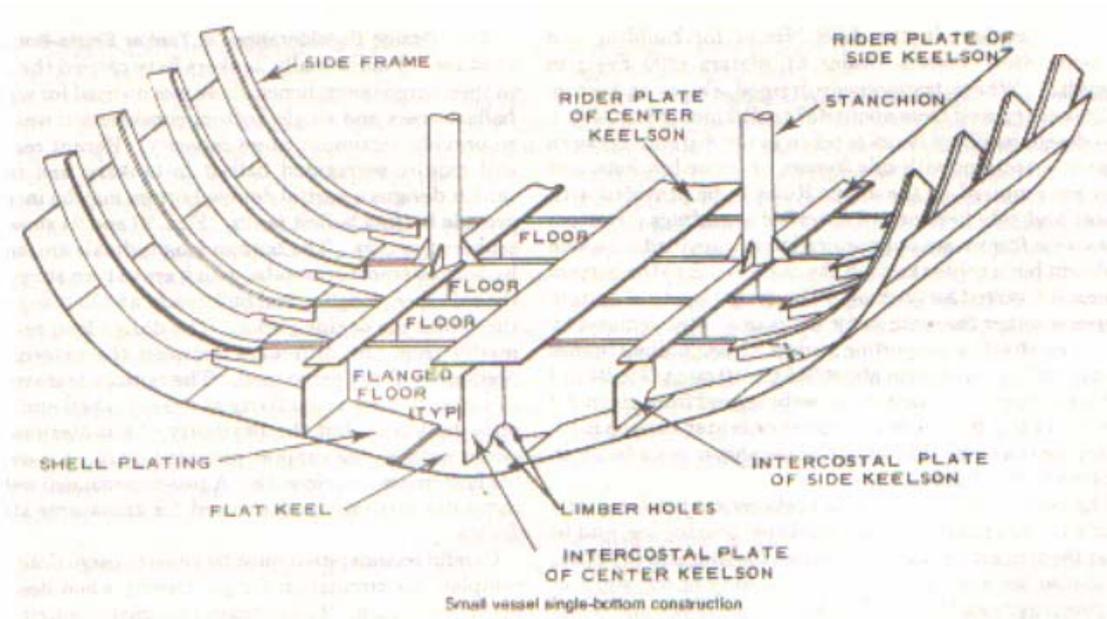


### Single-bottom construction

In some smaller vessels, a single-bottom construction is employed. The single bottom in smaller ships is similar to double-bottom construction but without the inner skin of plating. The upper edge of all plate floors must therefore be stiffened to improve their rigidity.

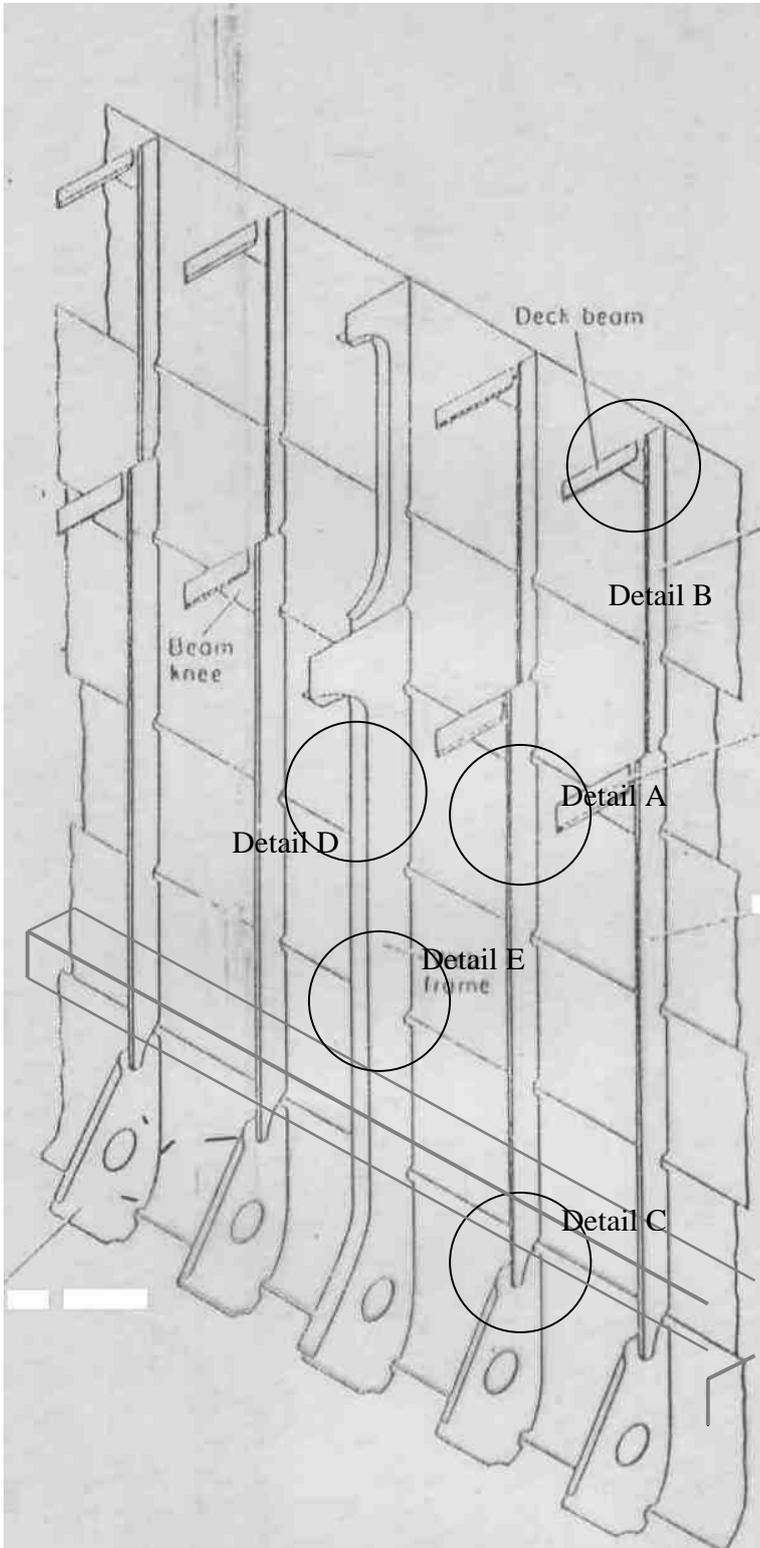
The single bottom is for vessels under 61 Meters (200 Feet) in Length." Where transversely framed, floors or bottom frames are spaced from about 457 to 610 mm (18 to 24 in.). They are required by the Rules to be provided with center and side keelsons of specified scantlings. Bottom transverse frames are not required to be provided with side keelsons, but a center keelson the same depth as the bottom frames is required for docking. A center girder or center keelson is required for docking.

The center keelson and side keelsons are intended primarily to keep the floors from buckling, or *tripping*, and to assist them in acting together. When the ship is in dry dock, the center keelson has the additional duty of transferring the pressure from the keel blocks into the floors and bulkheads, and thus into the hull as a whole. The scantlings of these members increase with the length of the ship because of their contribution to the longitudinal strength of the hull.



## 4. Side Construction

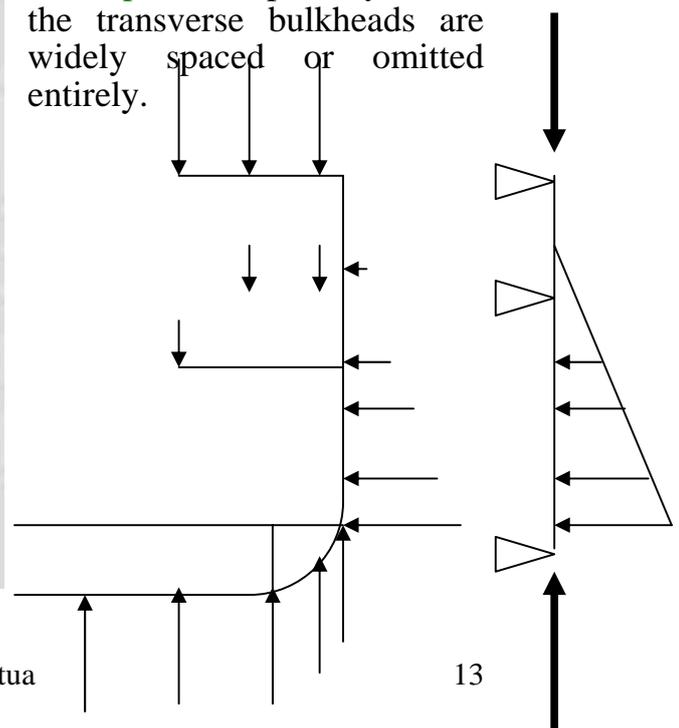
### Transverse Side Framing

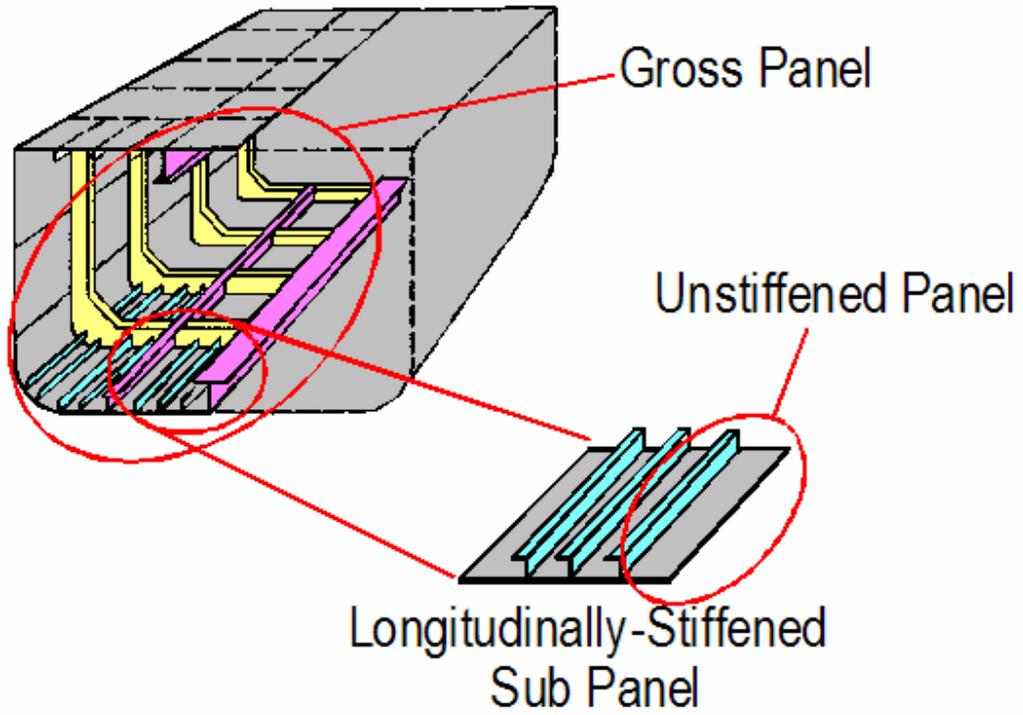


Transverse Side Frames help to resist water loads applied to the outside of the shell, they serve to stiffen the side plating against buckling. They furnish vertical support to the outboard ends of the beams supporting the several decks. In addition, side frames resist loads imposed by contact with piers, docks, and lock sides.

The brackets used for these connections must be carefully designed to avoid discontinuities and provide for the proper transition of loads.

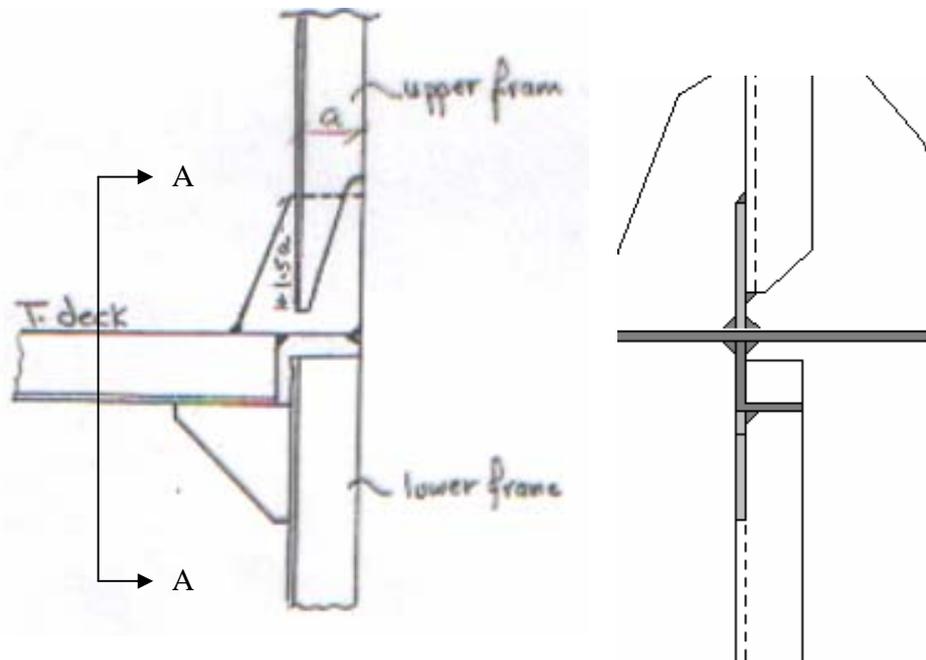
Another function of side frames is that of contributing resistance to racking stresses caused by rolling of the ship and by impact of seas against the topsides especially when the transverse bulkheads are widely spaced or omitted entirely.





Detail A  
Tween Deck Frame

A-A: Connection between lower and upper frames and tween deck

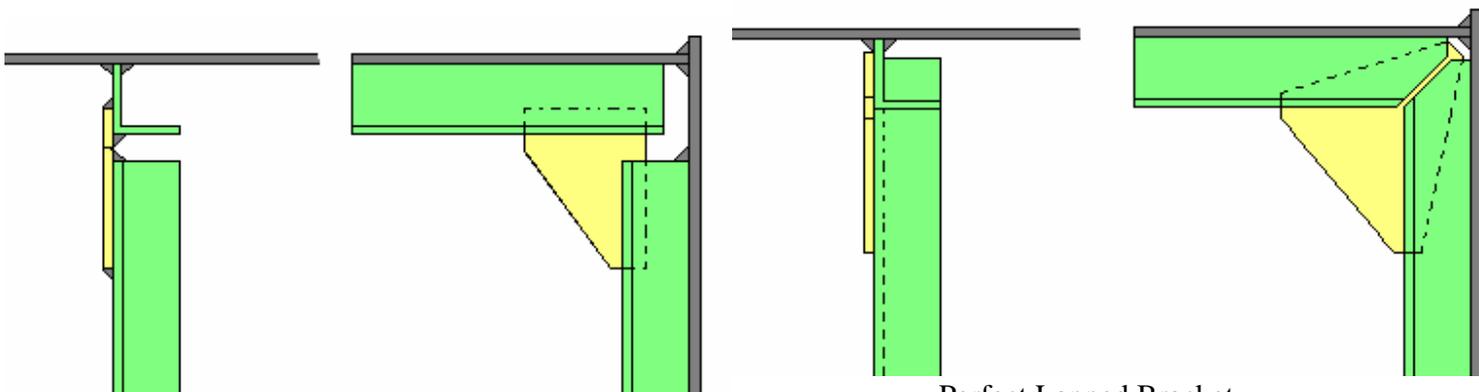
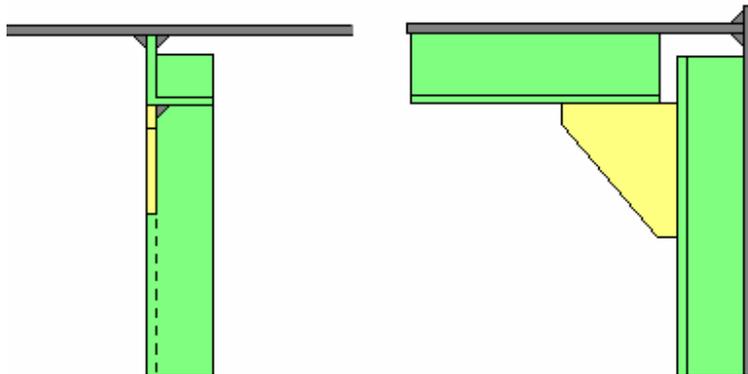


Prof. Khaled Atua

Ship Construction

**Types of Knee Bracket Connections**

Lapped Knee Bracket

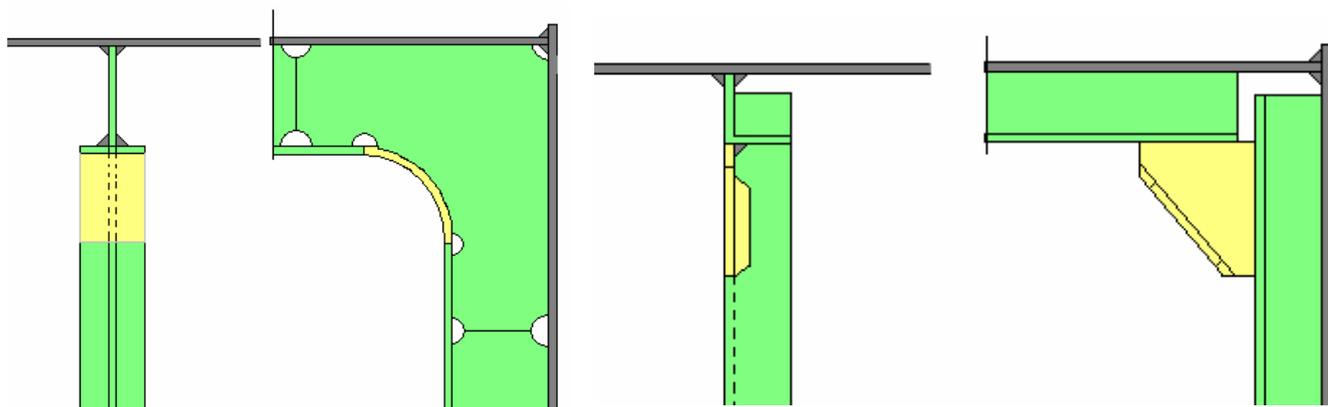


Butt Knee Bracket

- Stronger when subjected to tension
- Attachment of the beam to the frame
- Support the outboard end of the beam by reducing the effective span
- Minor resistance to ship's racking

Perfect Lapped Bracket

- Longer line of contact, hence, greater amount of weld and greater connectivity
- Firmer fixation of corner between deck and side plating
- Smoother stress flow between deck transverse and side frame through bracket



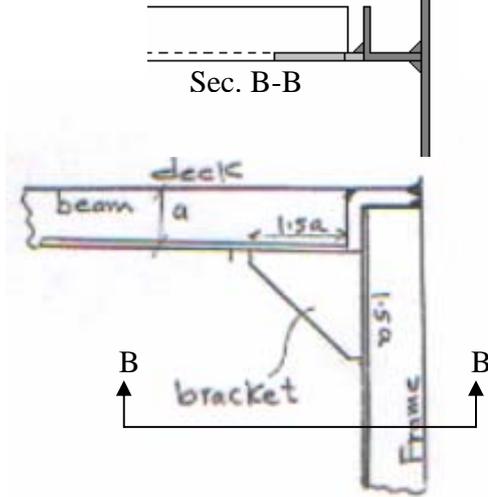
**Detail D**

Continuous Bracket

- Only at web frame and transverse deck web beam
- Made of a built T section (welded plates to form the bracket flange)
- Perfect stress flow between deck transverse beam and side web frame

Flanged Butt Knee Bracket

- Flanges are provided to create greater support instead of fitting a larger bracket
- Flange also helps to decrease the thickness of the bracket

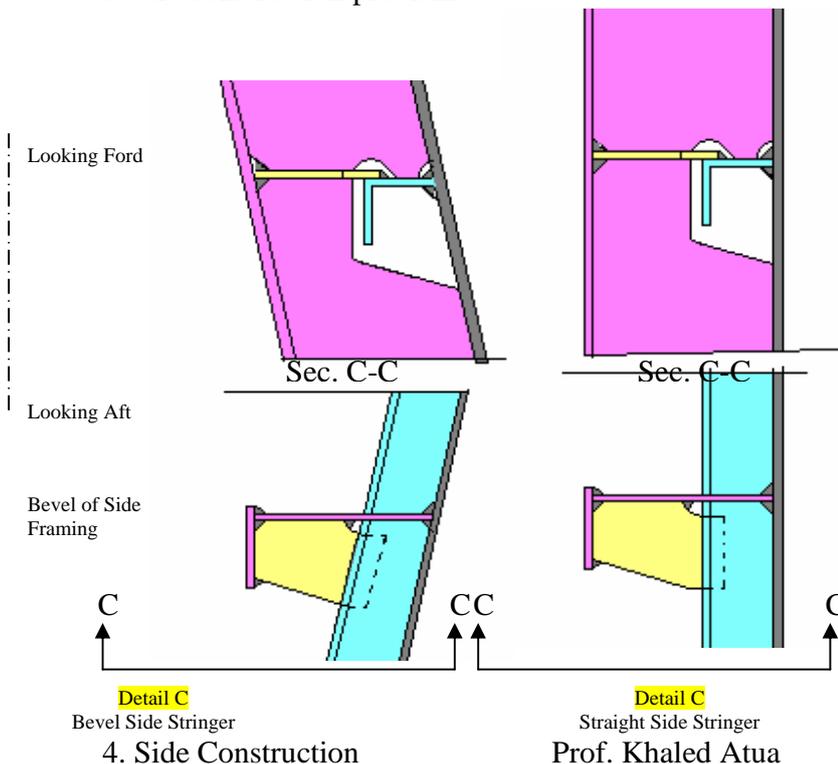


Detail B  
B-B: Knee Bracket

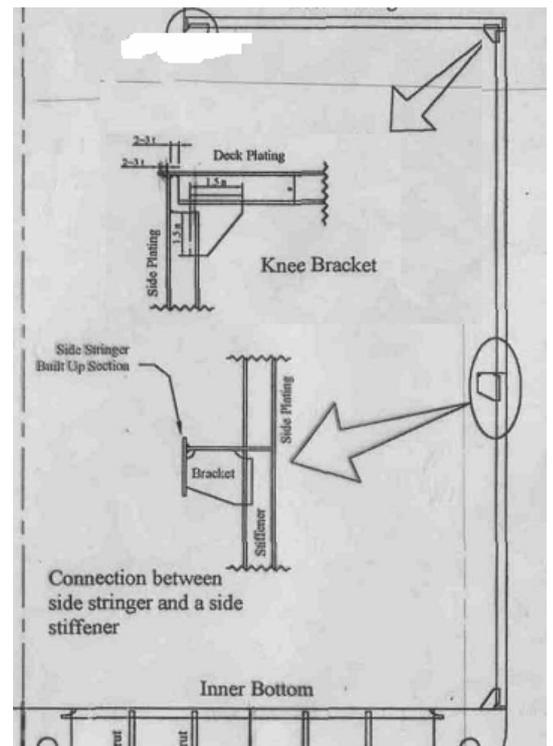
**Tween-deck Frames.** The section modulus of **tween-deck** frames plus plating, depends on the height and vertical **location** of the tween decks and the spacing of the frames. **Detail A.**

**Sections Used for Side Framing.** The sections most **commonly** used for frames are flat bars, inverted angles, bulb **plates**, and **T-sections**. The inverted angle *may be* either a rolled section or cut from a channel

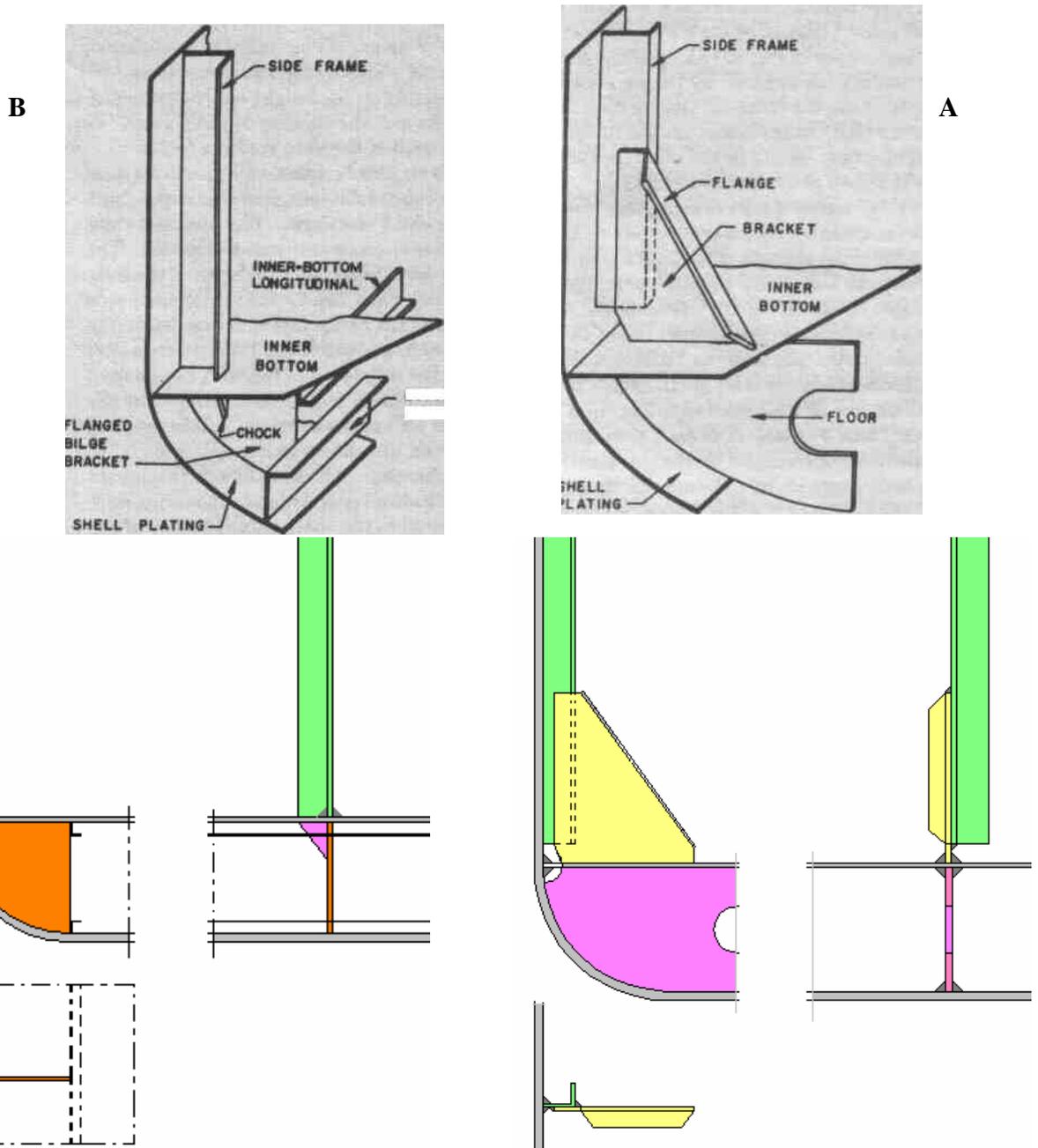
**Bevel of Side Framing.** The webs of side frames are set **normal** to the longitudinal **center plane** of the ship, and, as a result, are not normal to the shell. This facilitates alignment **with** transverse members, while the angularity at the shell does not cause a severe construction problem.



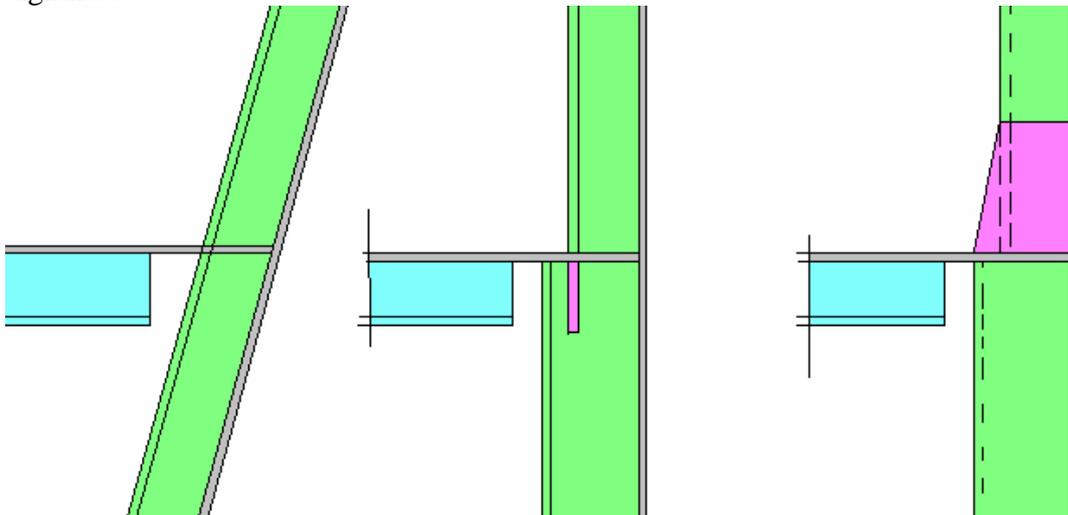
4. Side Construction



**Lower Connections of Hold Frames.** As shown in Fig A. The web of the bracket is welded to the inner bottom and the flange cut clear of the inner bottom. Where the hold frame brackets interfere with cargo stowage, they are eliminated by running the frame down to the inner bottom and welding it. In this case, the flange must be welded down and a chock provided. Fig. B shows the bilge bracket used as a connection for the lower end of the hold frame in cargo ships with a longitudinally framed double bottom. The bilge bracket is fitted at every frame not having a solid floor. The scantlings of the frame must be increased when the hold bracket is eliminated due to the longer span considered, since, for rule purposes, the length is measured to the top of the bracket

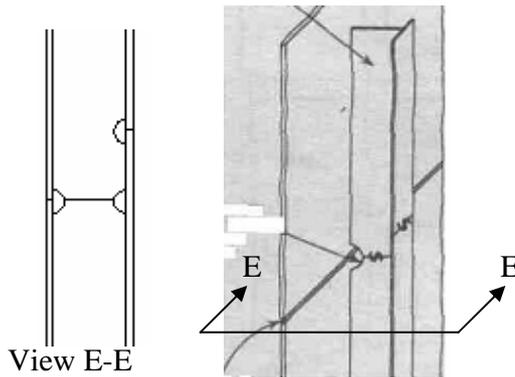


**Joints in Side Frames.** The hold frames are *generally* longer, and therefore heavier, than is necessary for the upper 'tween-deck frames, and, even if the hold size could be carried through in one long length, considerations of subassembly and erection usually make it desirable to fit the frames in more than one piece. At the resulting joints, effective continuity should be maintained. In welded construction, it might seem that a 100-percent butt-welded joint could be accepted at any desired place in the frame, but a backing strip should be used to ensure full penetration of the weld in the back side of the Hange, where welder's access and visibility are poor. ABS will accept a frame butt made in way of a deck or Hat, as in Fig. 30 (C). when there is assurance that the frames above and below the decks are lined up accurately. Careful workmanship, checked by inspection, is necessary in this connection. Where the frame is not considered as a continuous beam and the depth of the frame changes by more than about 25 mm (1 in.), provision should be made to maintain continuity of the Hanges. This can be done either by widening the shallower section, as in Fig. 30 (A), or, if the difference in depth of section is considerable, by fitting chocks on the deeper frame opposite the Hange of the shallower frame, as shown in Fig. 30 (B). Side frames should not pierce the tops of deep tanks; they should be cut, with the tank top continuous out to the shell to ensure its tightness.



**Crossing of Side Framing and Welded Shell Seams.**

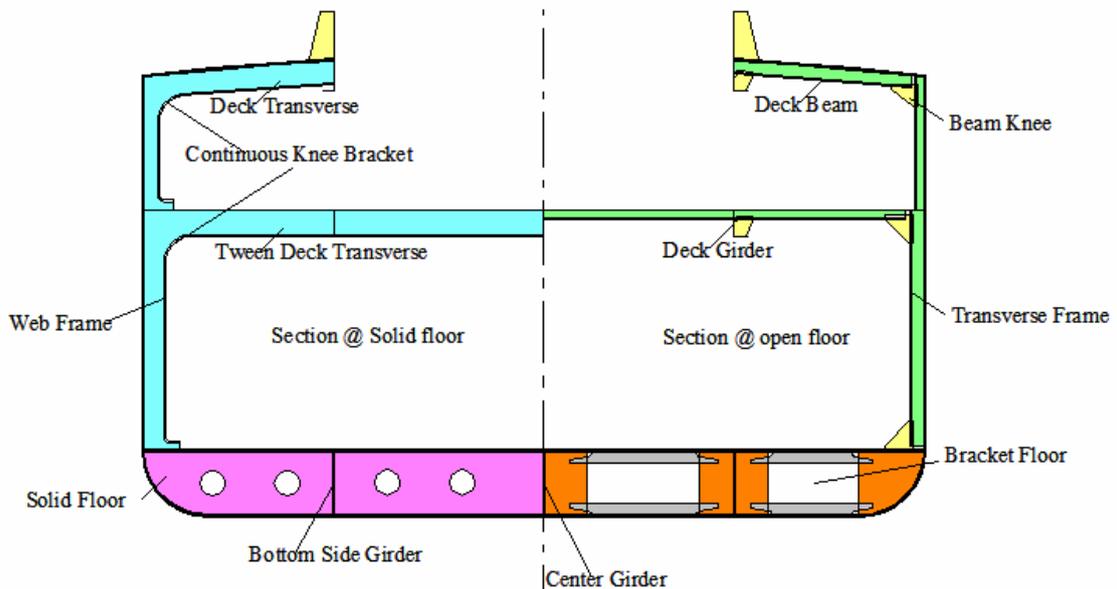
Wherever a welded frame crosses an erection seam weld in the shell plating, the web of the frame should be notched out to permit the seam weld to pass the frame intact and continuous, as shown in Fig. 31. This should be done generally where a nontight welded member crosses a continuous weld in a tight structure, such as stiffeners on a bulkhead or longitudinals crossing shell butts, except in the case of sub assembled plates, discussed in Subsection 14.5.



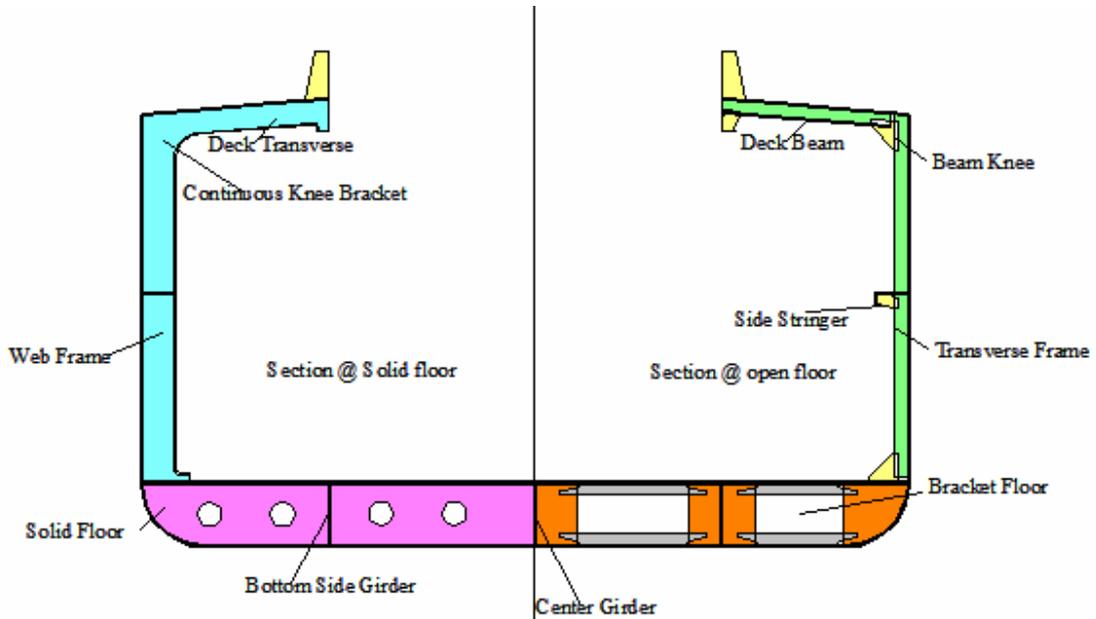
**Detail E**  
Side Framing and Welded Shell Seams.

- Scallops are provided to avoid intersection of two welding seams
- 

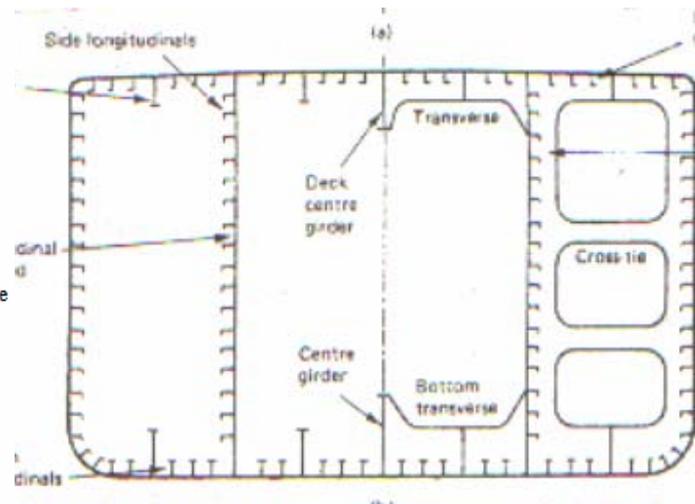
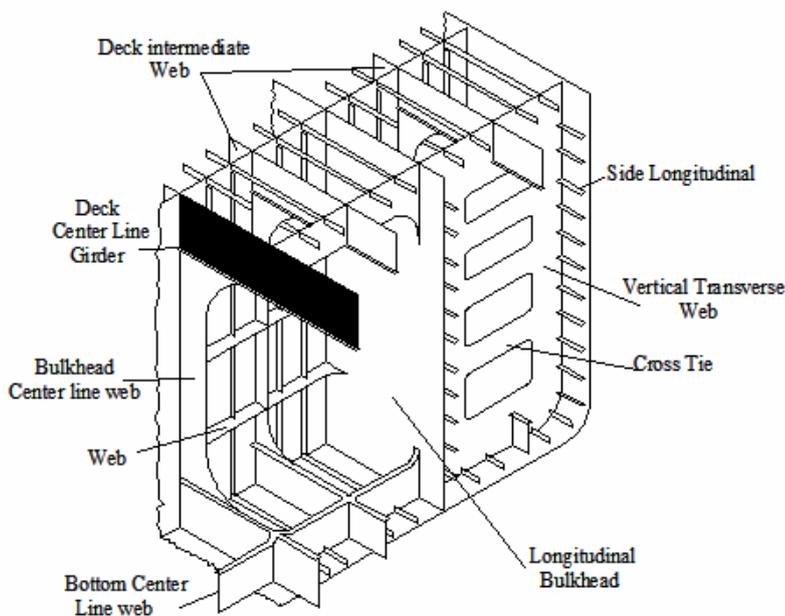
**Transversely framed Side Construction of a General Cargo Ship**

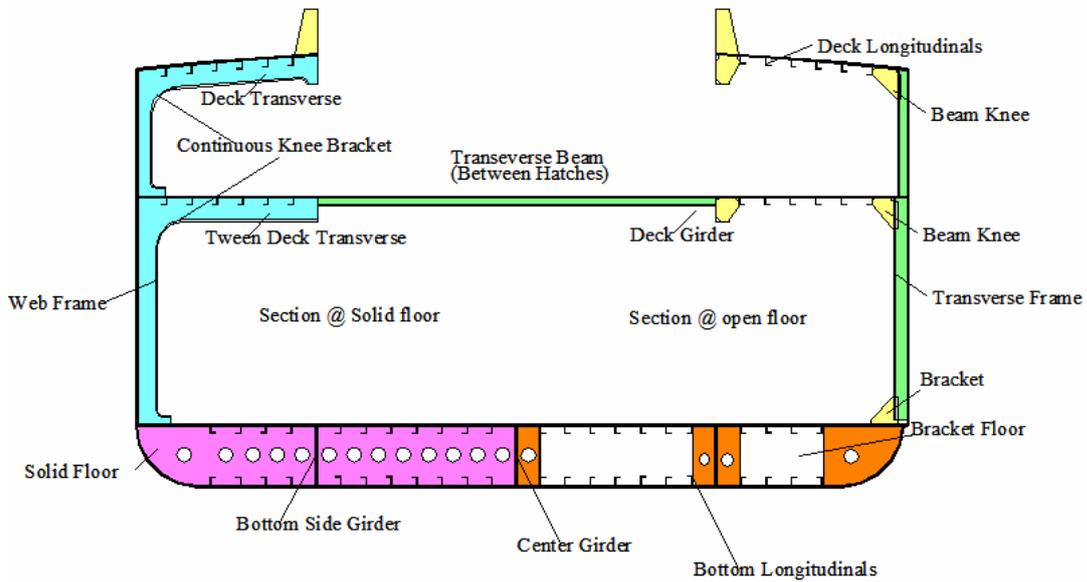


**Transversely framed Side Construction with a Side Stringer for a General Cargo Ship**



**Longitudinally framed Side Construction of an Oil Tanker**

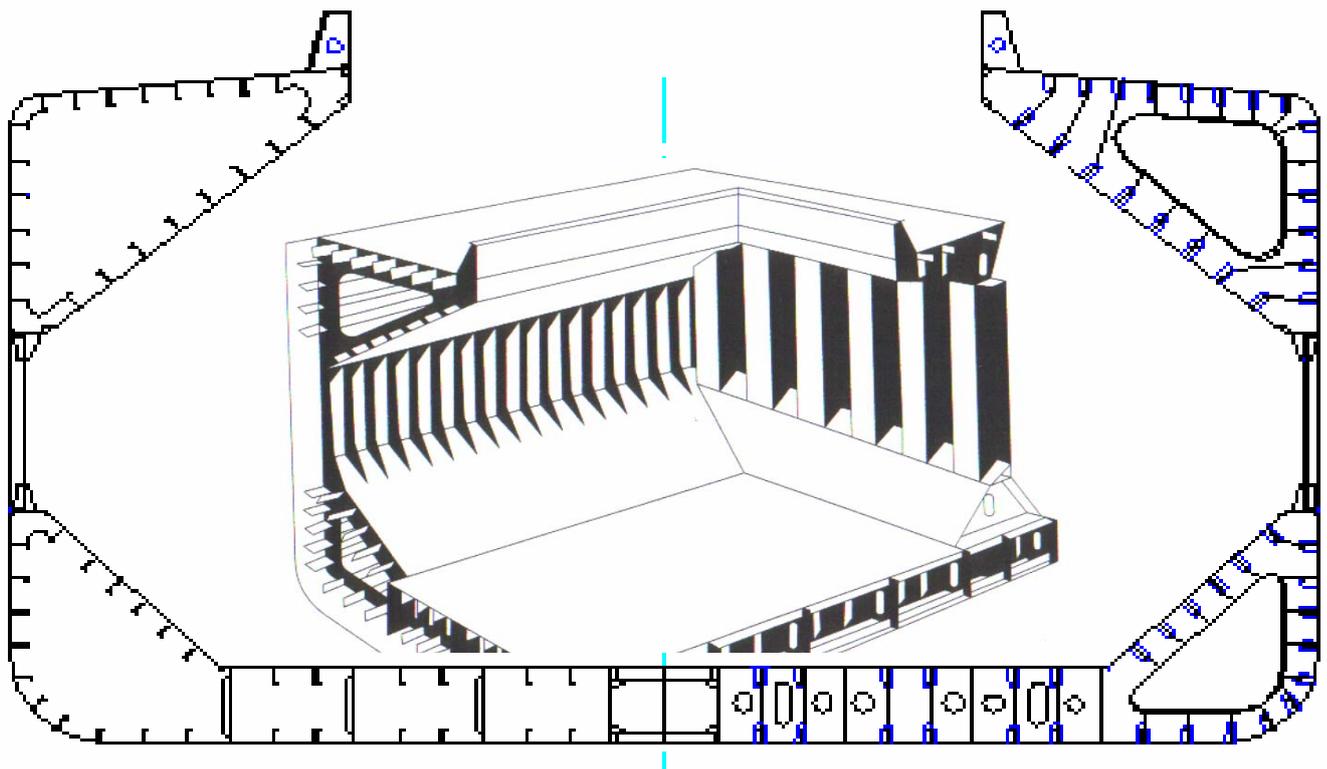


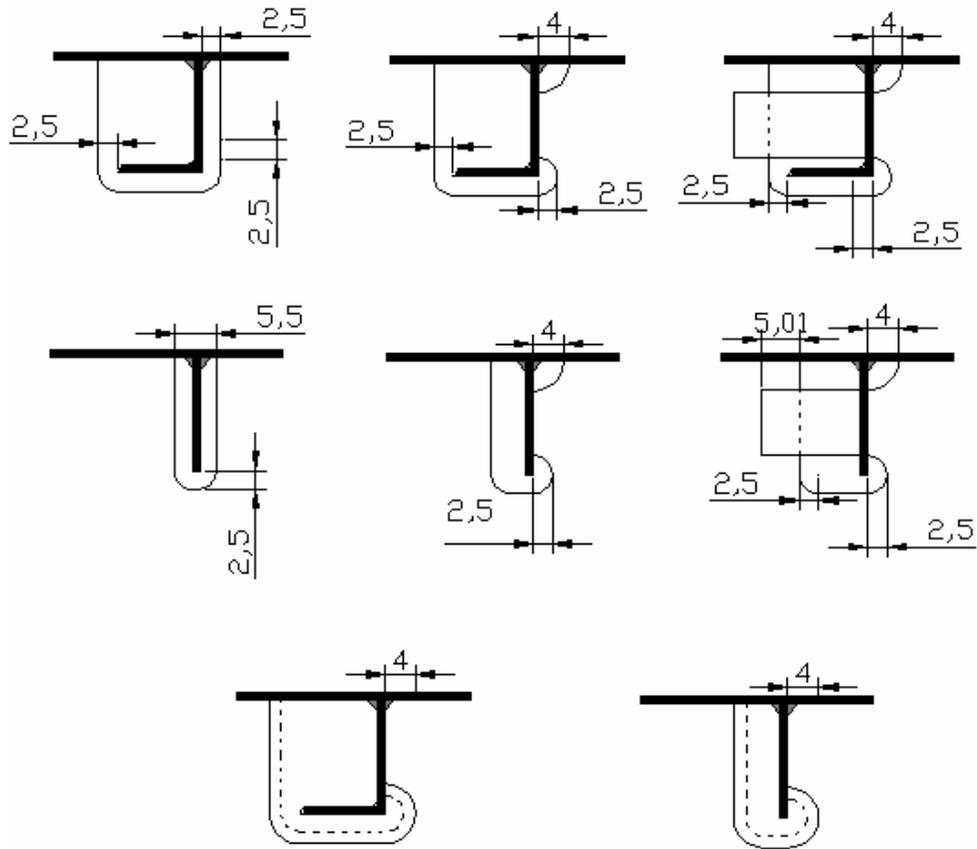


**Combined framed midship section of a General Cargo Ship**

For oil tankers, bulk carriers, general cargo vessels, containerships, and Great Lakes ore carriers, longitudinal framing is generally adopted, at least for the strength deck plating and bottom shell

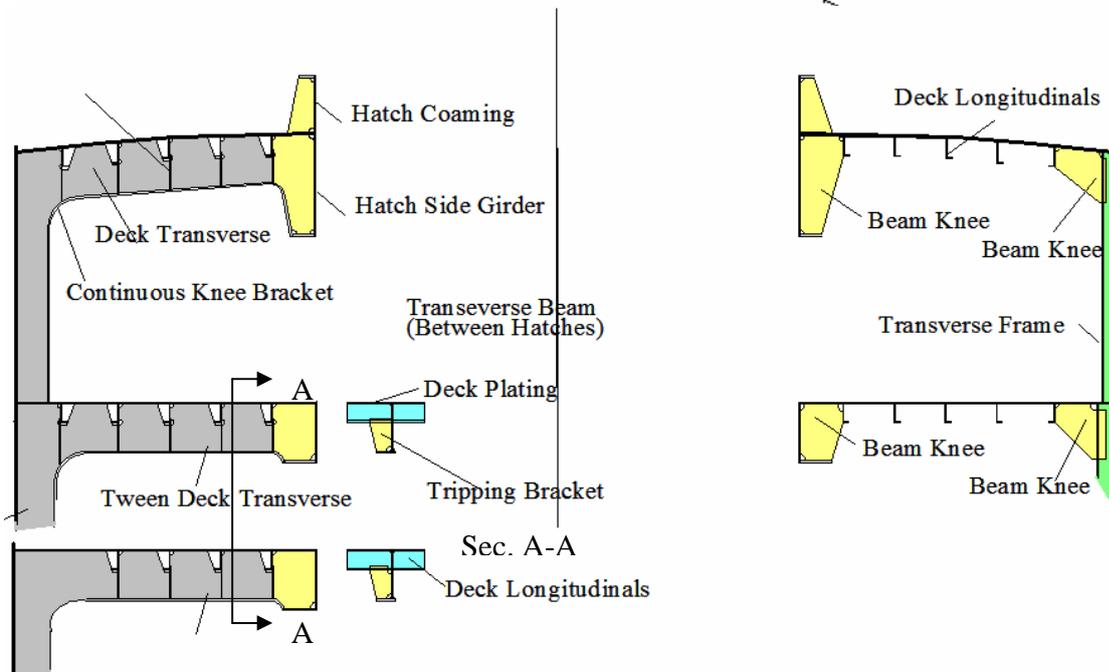
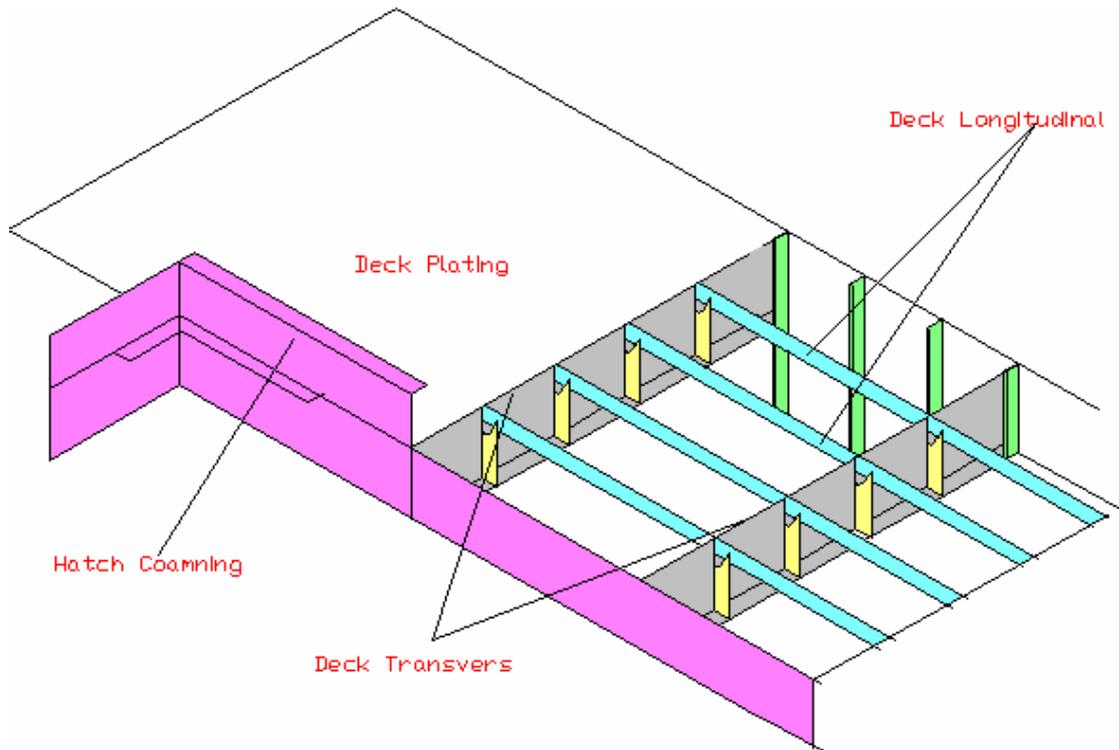
**Transversely framed Side Construction of a Bulk Carrier**



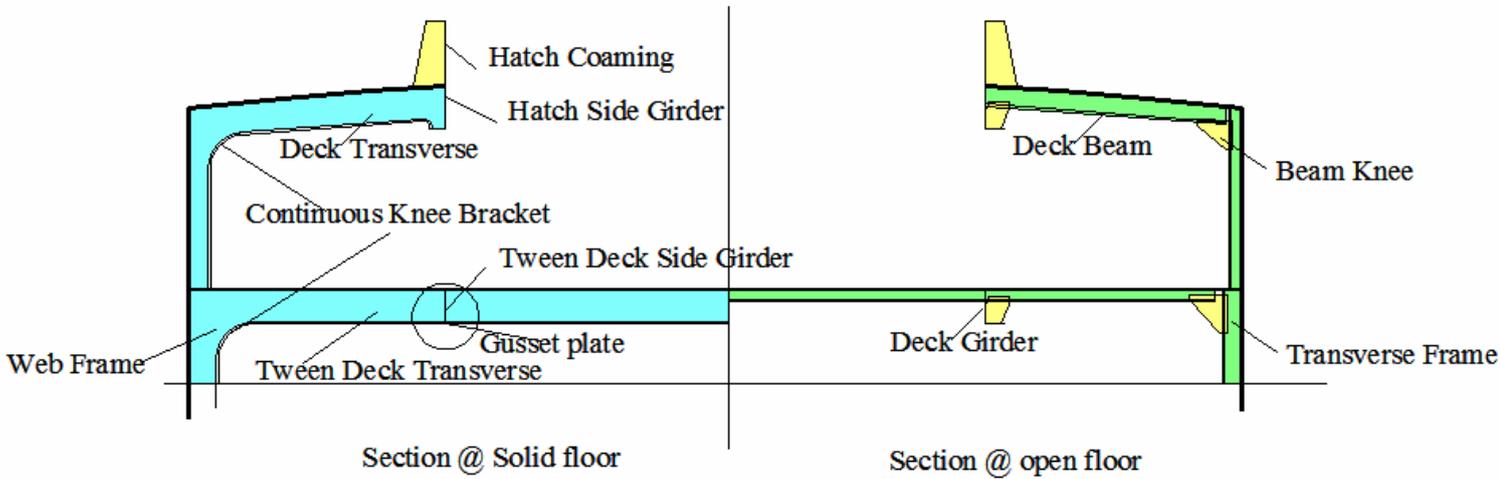
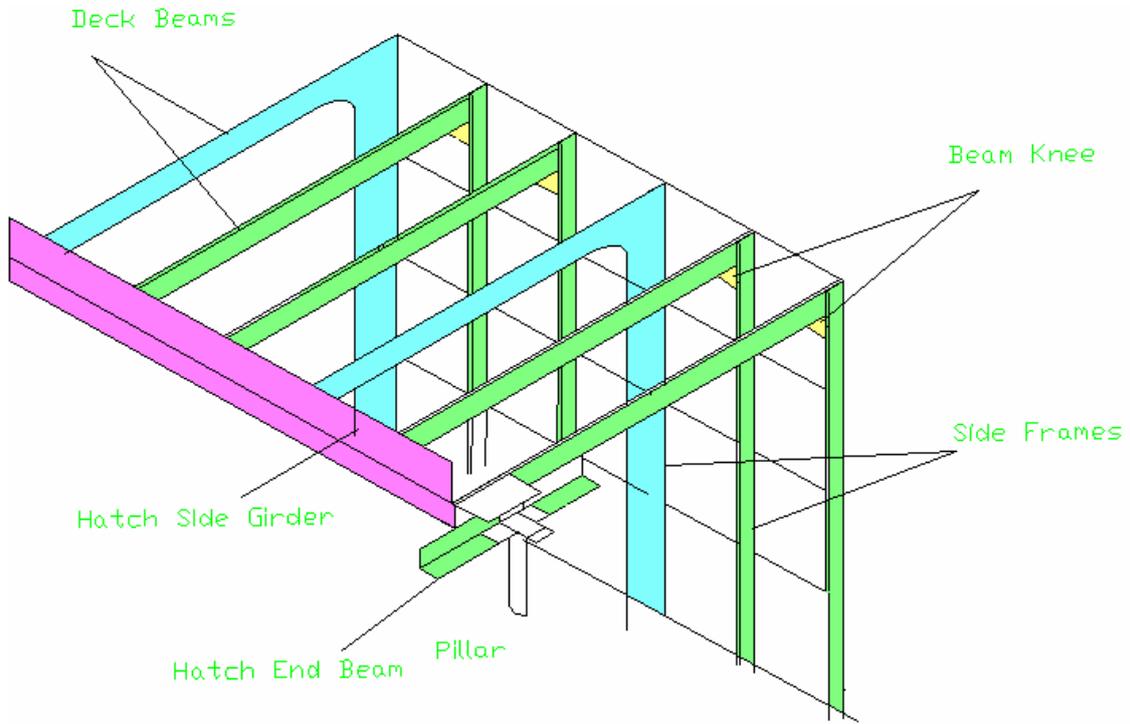


## 5. Deck Construction

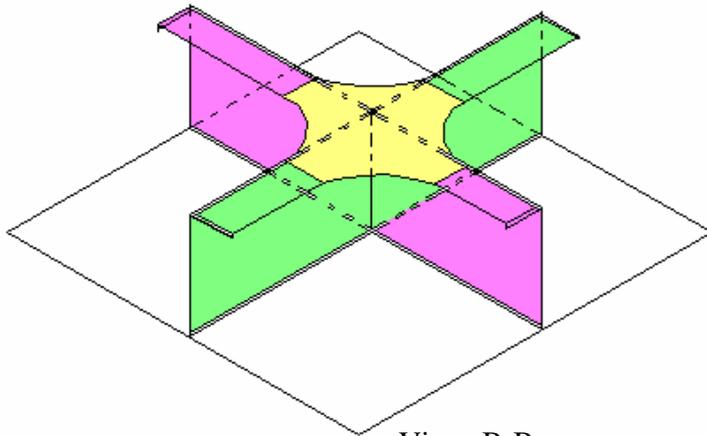
### Longitudinally Framed Deck



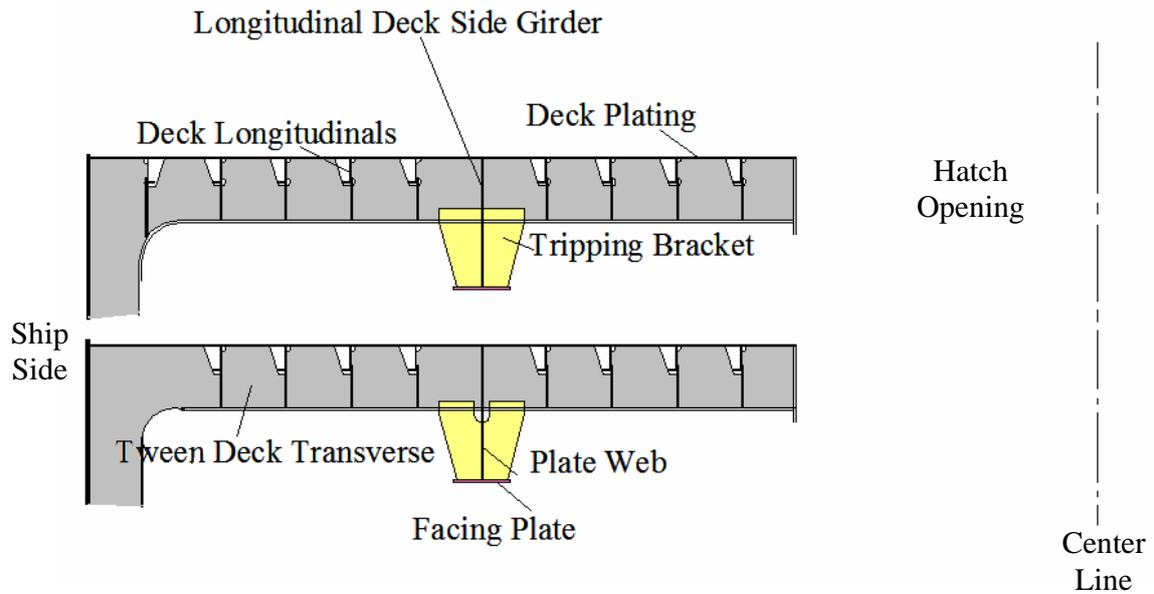
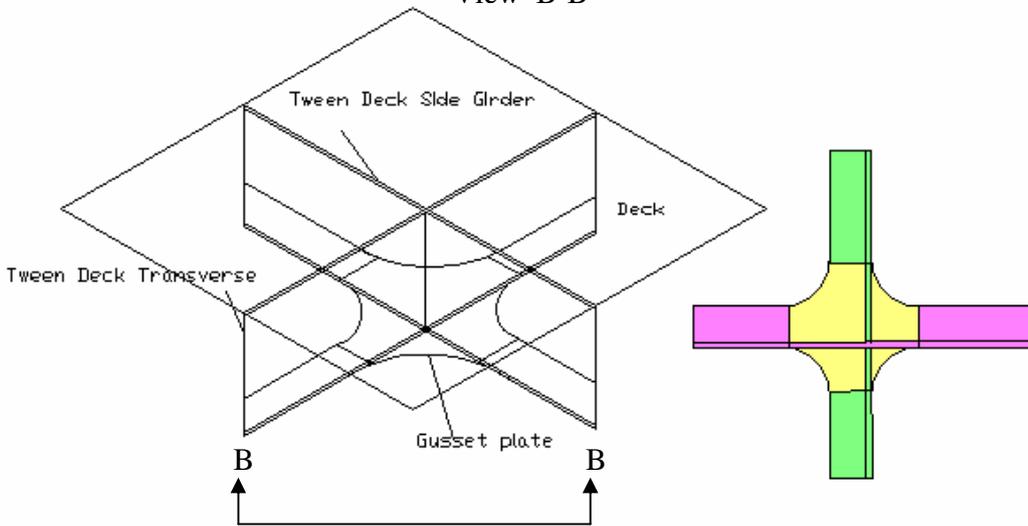
### Transversely Framed Deck

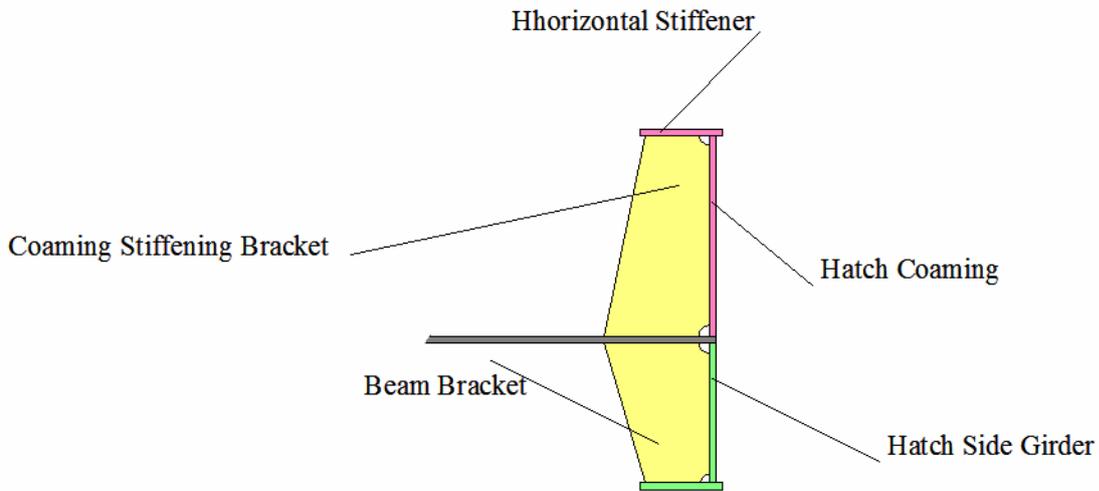


**Gusset Plate Detail.  
Connecting the face  
plates of the deck  
side girder and deck  
transverse**



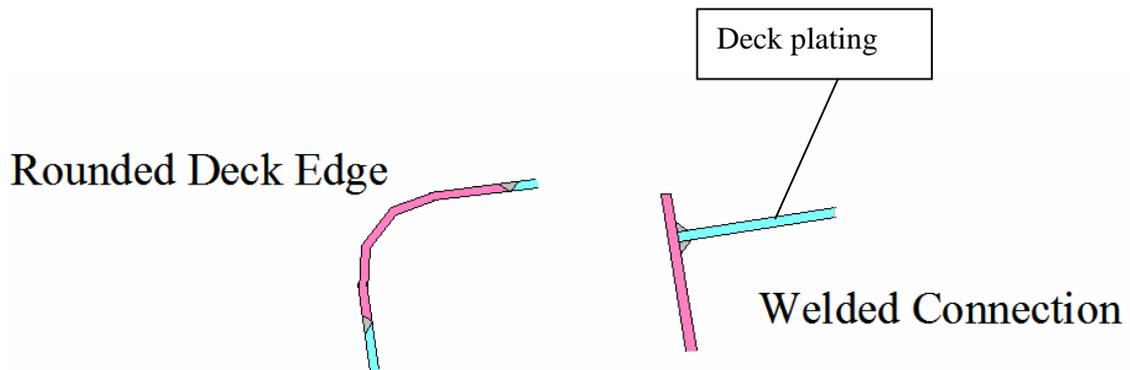
View B-B

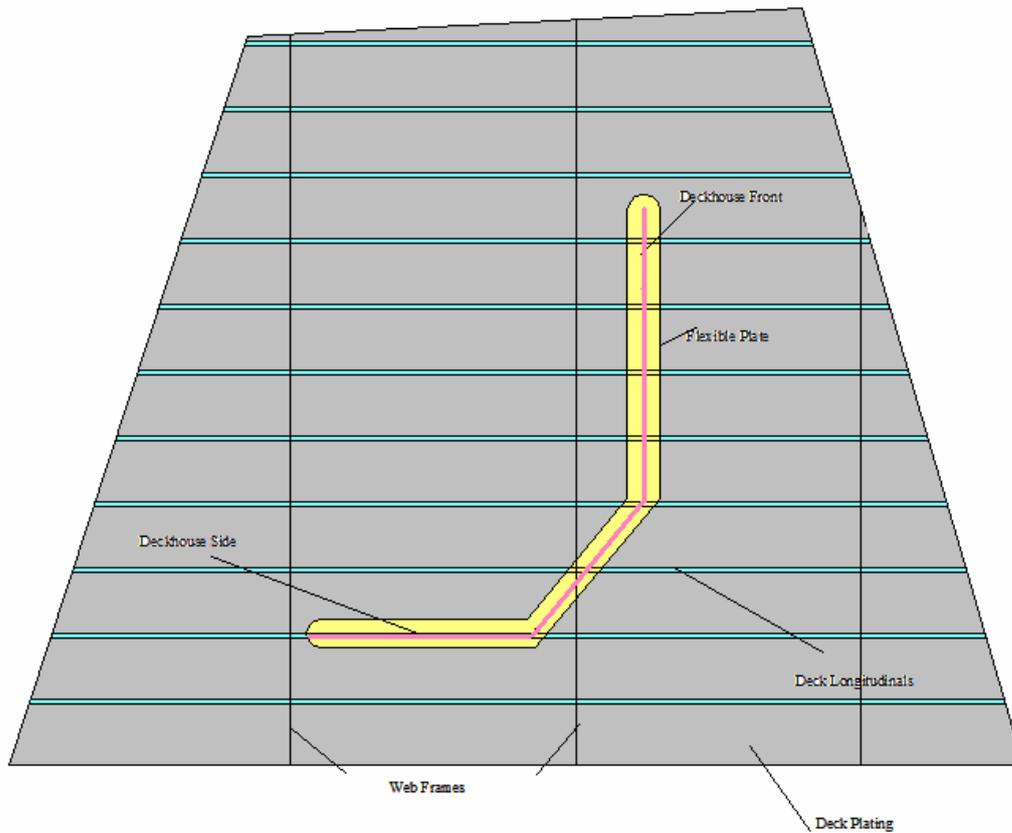




**Gunwale Connection**

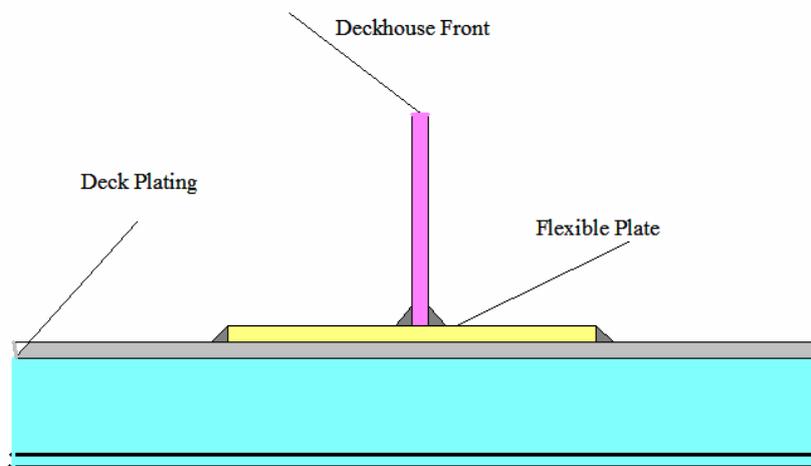
It is the area where the sheer strake meets the deck plating. The rounded gunwale has the advantage of eliminating the exposed plate edge of the strake. It has the disadvantages of reducing the deck area, the difficulty of making the transition to tee connection at the end of the parallel middle body, and additional construction cost and construction difficulty.





**Flexible Plate Construction at the end of the Deckhouse**

The edge of the deckhouse is brought down in the center of a deck doubler plate, which is attached to the deck only at the edges. This doubler plate relieves the hard spot formed by the deckhouse end landing on relatively flexible deck plating



## 6. Bulkhead Construction

### Bulkheads

The transverse watertight bulkheads subdivide the ship into a number of **watertight** compartments and their number is dictated by classification society **regulations**. **Oiltight** bulkheads form the boundaries of tanks used for the **carriage** of liquid cargoes or fuels. Non-watertight bulkheads are any other **bulkheads** such as engine casings, accommodation partitions or stores **compartments**.

#### Watertight bulkheads

In addition to subdividing the ship, transverse bulkheads also provide considerable structural strength as support for the decks and to resist deformation caused by broadside waves (racking). **The** spacing of watertight bulkheads, which is known as the watertight subdivision of the ship, is governed by rules dependent upon ship type, size, etc. All ships must have:

- (1) A collision or fore peak bulkhead which is to be positioned not less than 0.05 **X** length of the ship, nor more than 0.08 **X** length of the ship, from the forward end of the load **waterline**.
- (2) An after peak bulkhead which encloses the stern tube(s) and rudder trunk in a watertight compartment.
- (3) A bulkhead at each end of the machinery space; the after bulkhead may, for an aft engine room, be the after peak bulkhead.

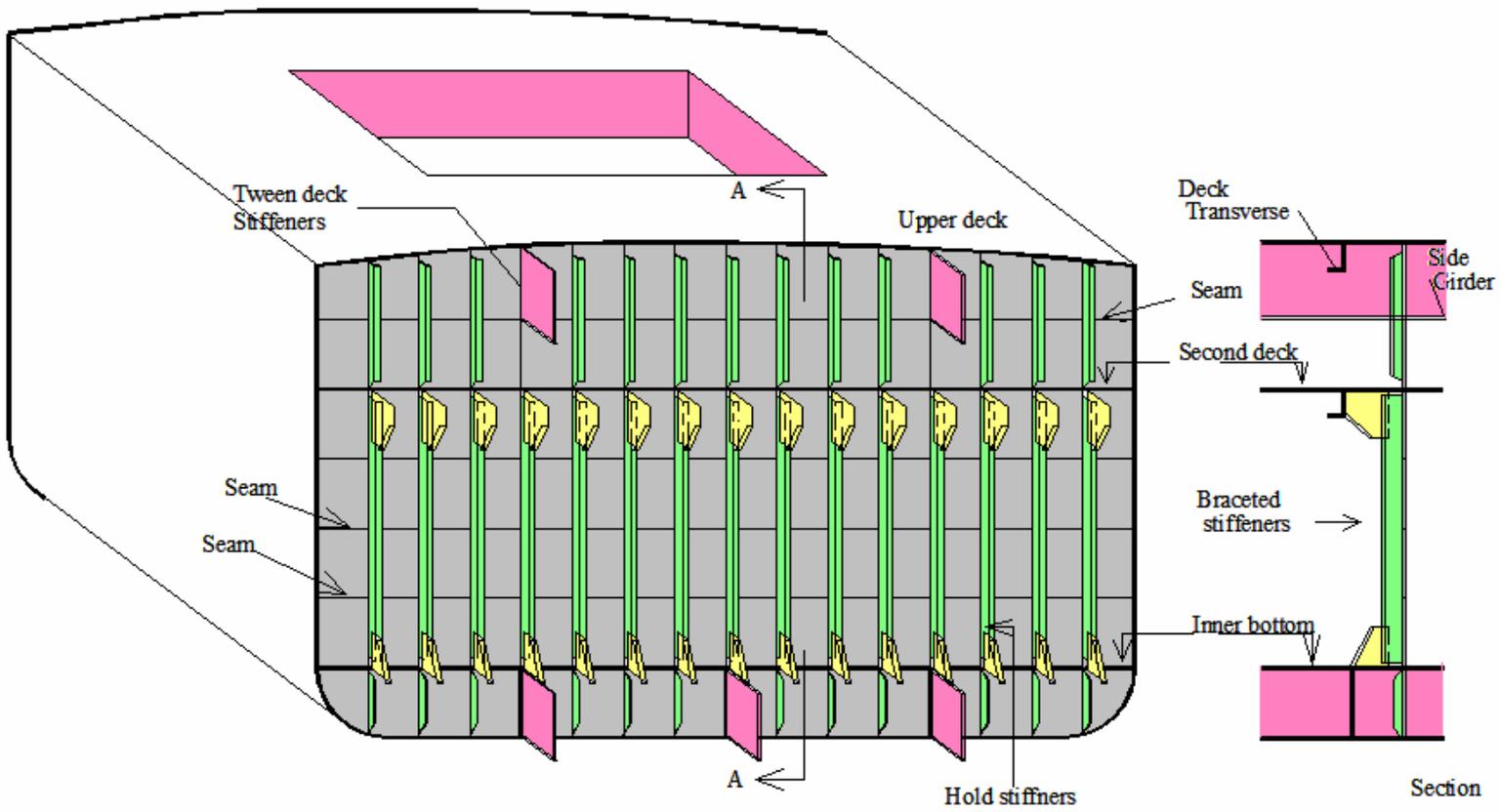
Additional bulkheads are to be fitted according to the vessel's length, e.g. a ship between 145 and 165 **m** long must have 8 bulkheads with machinery midship and 7 bulkheads with machinery aft.

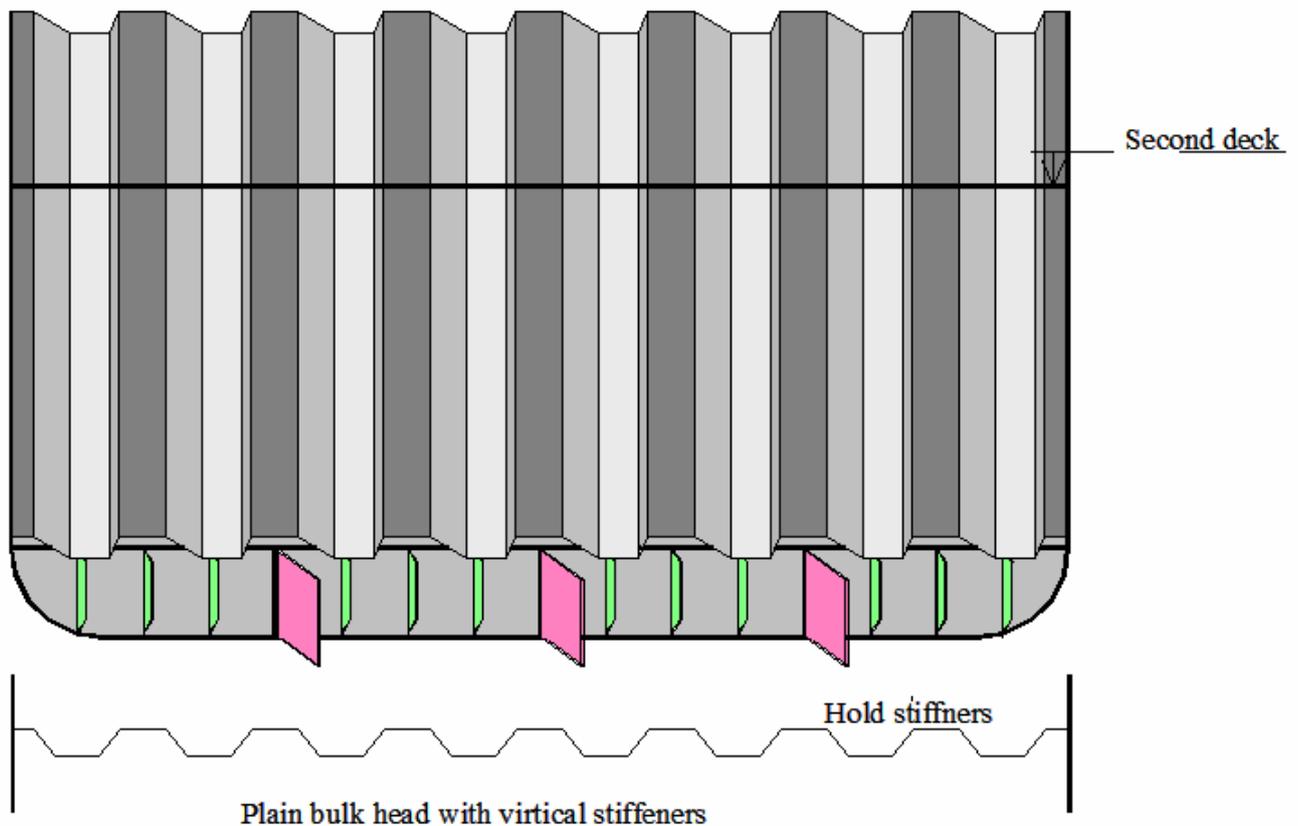
Fitting less than the standard number of bulkheads is permitted in approved circumstances where additional structural compensation is provided. Watertight bulkheads must extend to the freeboard deck but may rise to the uppermost continuous deck. The aft peak bulkhead may extend only to the next deck above the load waterline, where the construction aft of this deck is fully watertight to the shell. The purpose of watertight subdivision and the spacing of the bulkheads is to provide an arrangement such that if one compartment is flooded between bulkheads the ship's waterline will not rise above the margin line. The margin line is a line drawn parallel to and 76 mm below the upper surface of the bulkhead deck at the ship's side. The subdivision of passenger ships is regulated by statutory requirements which are in excess of classification society rules for cargo ships, but the objects of confining flooding and avoiding sinking are the same.

#### *Construction of watertight bulkheads*

Watertight bulkheads, because of their large area, are formed of several **strakes** of plating. They are welded to the shell, deck and tank top. The plating strakes are horizontal and the stiffening is vertical. Since water pressure in a tank increases with depth and the watertight bulkhead must withstand such loading, the bulkhead must have increasingly greater strength towards the base. This is achieved by increasing the thickness of the horizontal **strakes** of plating **towards** the bottom. The collision bulkhead must have plating some 12% thicker than other watertight bulkheads. Also, plating in the aft peak bulkhead around the **stemtube** must be doubled or increased in thickness to reduce vibration. The bulkhead is stiffened by vertical bulb plates or

toe-welded angle bar stiffeners spaced about 760 mm apart. This spacing is reduced to 610 mm for collision and oiltight bulkheads. The ends of the stiffeners are bracketed to the tank top and the deck beams. In tween decks, where the loading is less, the stiffeners may have no end connections.

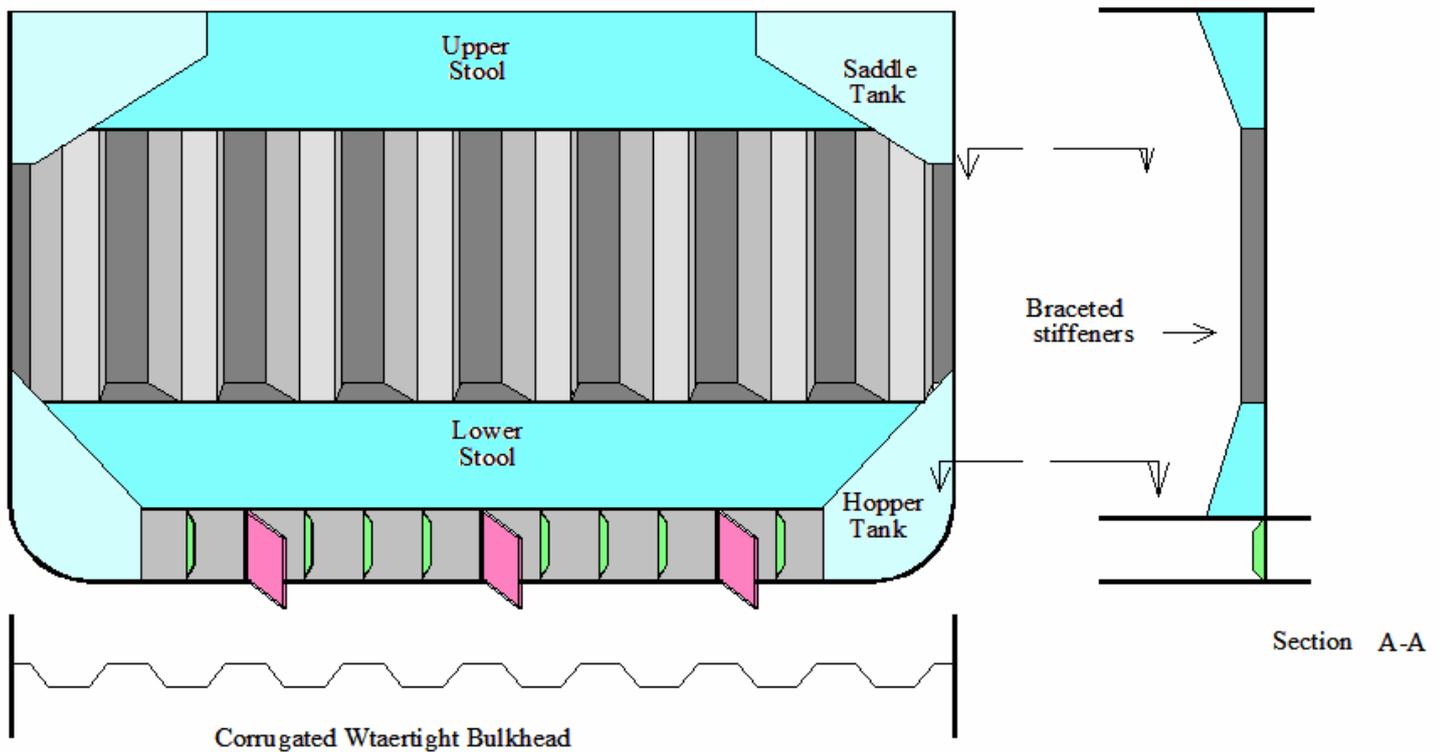




### **Corrugated watertight bulkheads**

The use of corrugations or **swedges** in a plate instead of welded stiffeners produces as strong a structure with a reduction in weight. The troughs are vertical on transverse bulkheads but on longitudinal bulkheads they must be horizontal in order to add to the longitudinal strength of the ship. The corrugations or **swedges** are made in the plating **strakes** prior to fabrication of the complete bulkhead. As a consequence, the strakes run vertically and the plating must be of uniform thickness and adequate to support the greater loads at the bottom of the bulkhead. This greater thickness of plate offsets to some extent the saving in weight through not adding **stiffeners** to the bulkhead. The edges of the corrugated bulkhead which join to the shell plating may have a stiffened flat plate fitted to increase transverse strength and simplify fitting the bulkhead to the shell. On high bulkheads with vertical corrugations, diaphragm plates are fitted across the troughs. This prevents any possible collapse of the corrugations.

A watertight floor is fitted in the double bottom directly below every main transverse bulkhead. Where a watertight bulkhead is penetrated, e.g. by pipework, a watertight closure around the penetration must be ensured by a collar fully welded to the pipe and the bulkhead.



### ***Testing of watertight bulkheads***

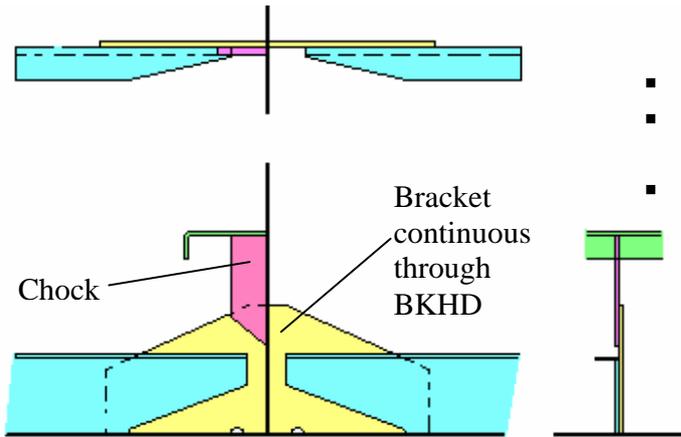
The main fore and aft peak bulkheads must be tested by filling with water to the load **waterline**. Subdividing watertight bulkheads are tested by hosing down. **Oiltight** and tank bulkheads must be tested by a head of water not less than 2.45 m above the highest point of the tank.

### **Non-watertight bulkheads**

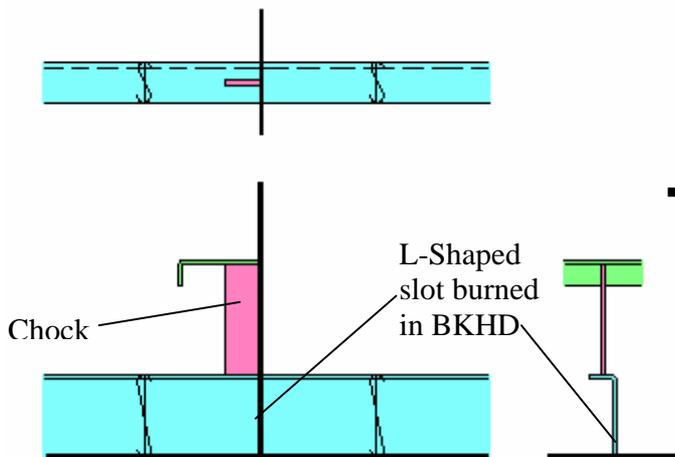
Any bulkheads other than those used as main subdivisions and tank boundaries may be non-watertight. Examples of these are engine room casing bulkheads, accommodation partitions, store room divisions, etc. Wash bulkheads fitted in deep tanks or in the fore end of a ship are also examples of non-watertight bulkheads. Where a non-watertight bulkhead performs the supporting function similar to a pillar, its stiffeners must be adequate for the load carried. In all other situations the non-watertight bulkhead is stiffened by bulb plates or simply flat plates welded edge on. Corrugated and **swedged** bulkheads can also be used for non-watertight bulkheads.

**Trough-Longitudinals (Through Watertight Bulkhead)**

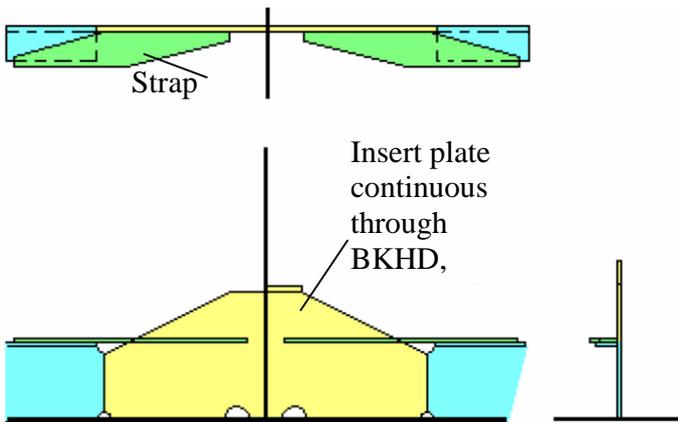
The purpose of this section is to demonstrate how to maintain the continuity of the longitudinal stiffeners through the transverse watertight bulkheads



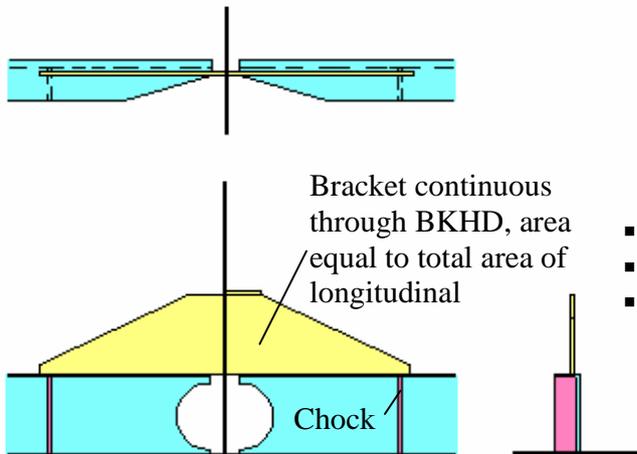
- The most preferable
- Full strength and connection of longitudinal
- Least structural discontinuity



- Attention is needed for welding between bracket and the longitudinal to maintain the section modulus



- Attention is needed for welding between bracket and the longitudinal to maintain the section modulus
- The flat bars is necessary to prevent fracture at the bracket toes

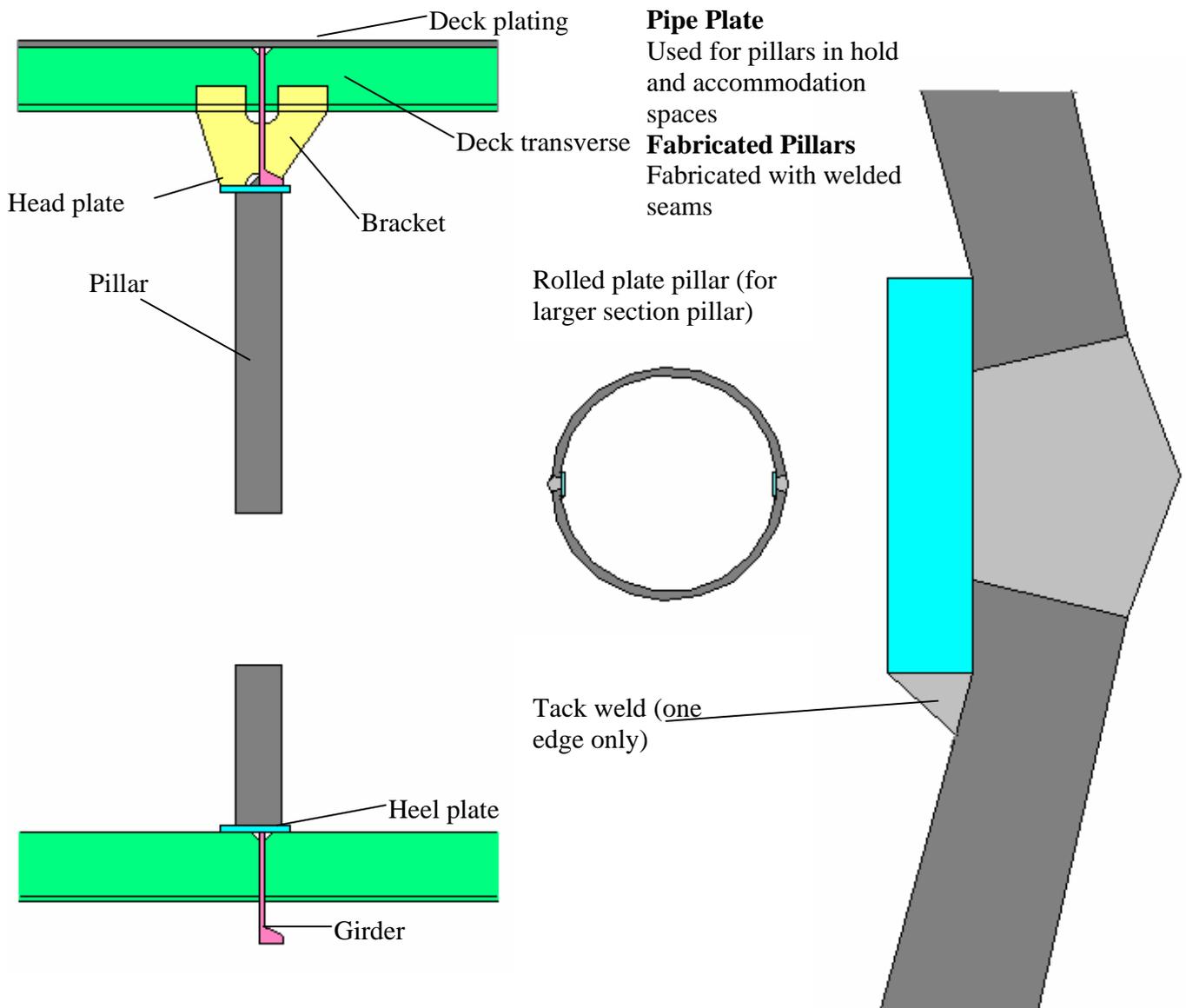


- Less strength and area of longitudinal
- Limited to small ships only
- The flat bars is necessary to prevent fracture at the bracket toes

### 7. Pillars Construction

Pillars provide a means of transferring loads between decks and fastening together the structure in a vertical direction. The pillars, which transfer loads, as in the cargo holds or beneath items of machinery, are largely in compression and require little or no bracketing to the surrounding structure. Pillars, which tie structure together and are subjected to tensile forces are adequately bracketed at the head or top and the heel or bottom.

Hold pillars are usually large in section and few in number to reduce interference with cargo stowage to a minimum. Pillars are provided to reduce the need for heavy webs to support the hatch girders or end beams. The use of pillars also enables a reduction in size of the hatch girders and beams, since their unsupported span is reduced. Where pillars are fitted between a number of vertical decks they should be in line below one another to efficiently transfer the loads.



Hold pillar sections are usually a hollow fabricated shape manufactured from steel plate. Typical sections are round, square and sometimes octagonal. Machinery space pillars are usually fabricated from sections and, while smaller in dimensions than hold pillars, a greater number are fitted (*Figure 5.20*). Additional structural material must be provided at the head and heel of pillars to evenly distribute the load. At the head a plate is used, often with tripping brackets to surrounding structure. At the heel an insert plate or doubling plate is used, with or without brackets depending upon the type of loading (*Figure 5.21*).

Solid pillars may be fitted in accommodation spaces or under points of concentrated loading. Solid round bar up to about 100 mm diameter is fitted, again with head and heel plates to spread the load.

