



ΣΧΟΛΗ ΜΗΧΑΝΙΚΩΝ  
ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΙΚΩΝ  
ΜΕΤΑΠΤΥΧΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΣΠΟΥΔΩΝ

# Το σχέδιο της μέσης τομής πλοίου

A. Θεοδουλίδης

# Σχέδιο Μέσης Τομής

- Αποτελεί ένα από τα βασικότερα κατασκευαστικά σχέδια του πλοίου.
- Είναι αντιπροσωπευτικό της δομής της μεταλλικής κατασκευής στην περιοχή φορτίου (cargo area).
- Περιέχει πολλές χρήσιμες πληροφορίες για το πλοίο και τη φόρτωσή του
- Δείχνει σημαντικές κατασκευαστικές λεπτομέρειες.

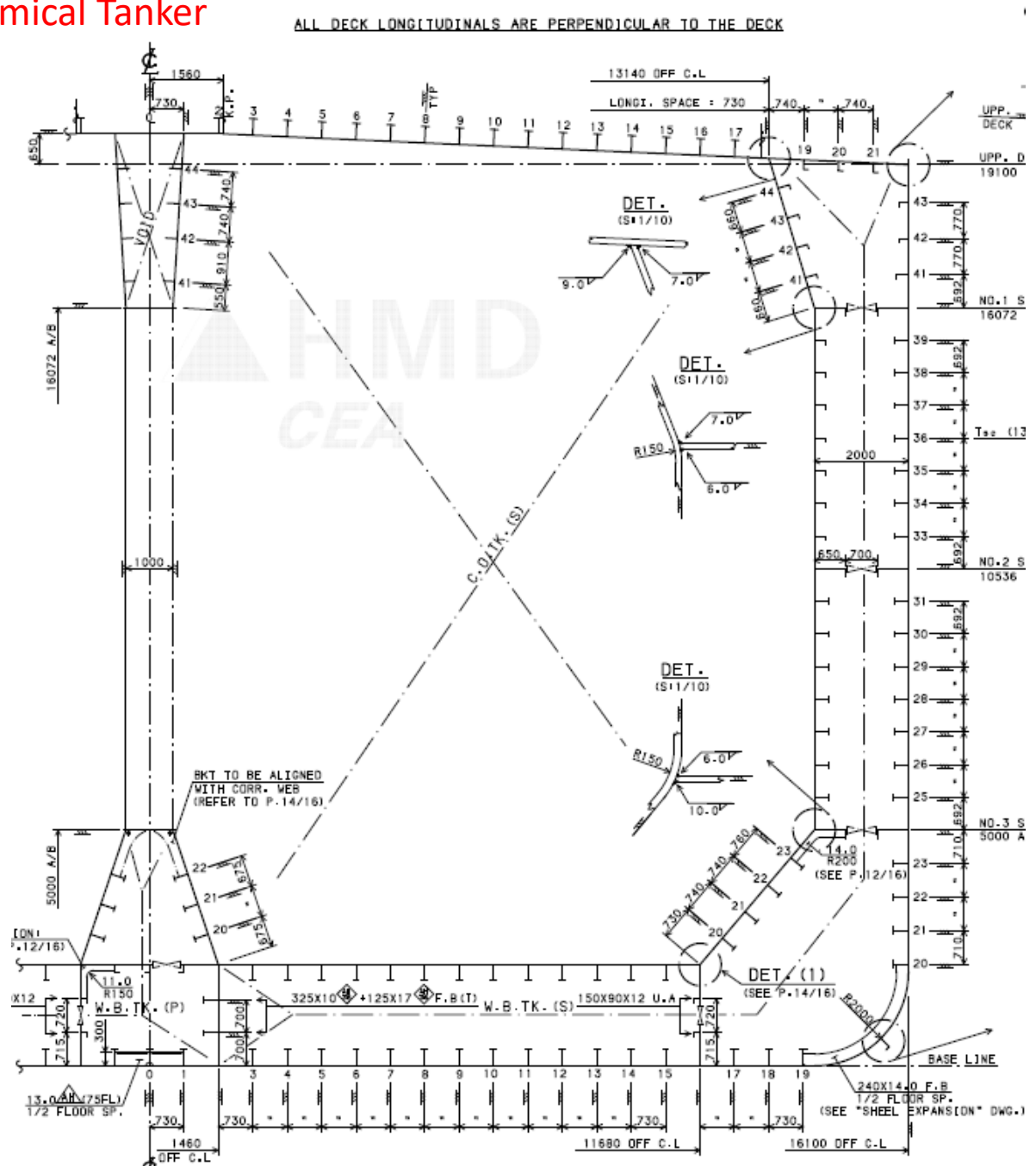
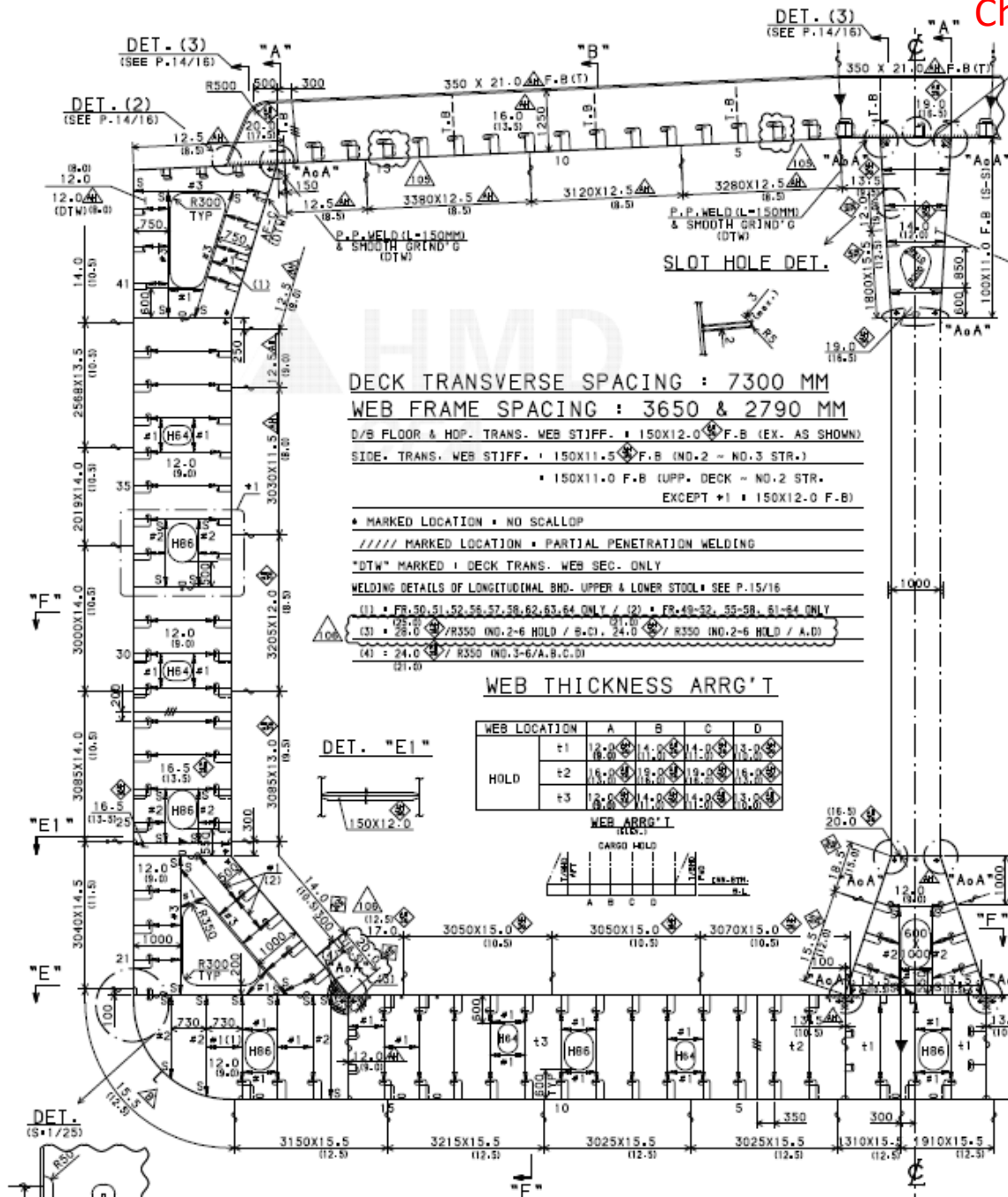
# Βασικά κατασκευαστικά σχέδια πλοίου

- Midship Section
- Shell expansion
- Profile and Decks
- Bulkheads
- Transverse Sections
- Double Bottom Construction
- Fore End Construction
- Aft End Construction
- Engine Room Construction

# TYPICAL WEB SECTION

# Chemical Tanker

# ORDINARY SECTION



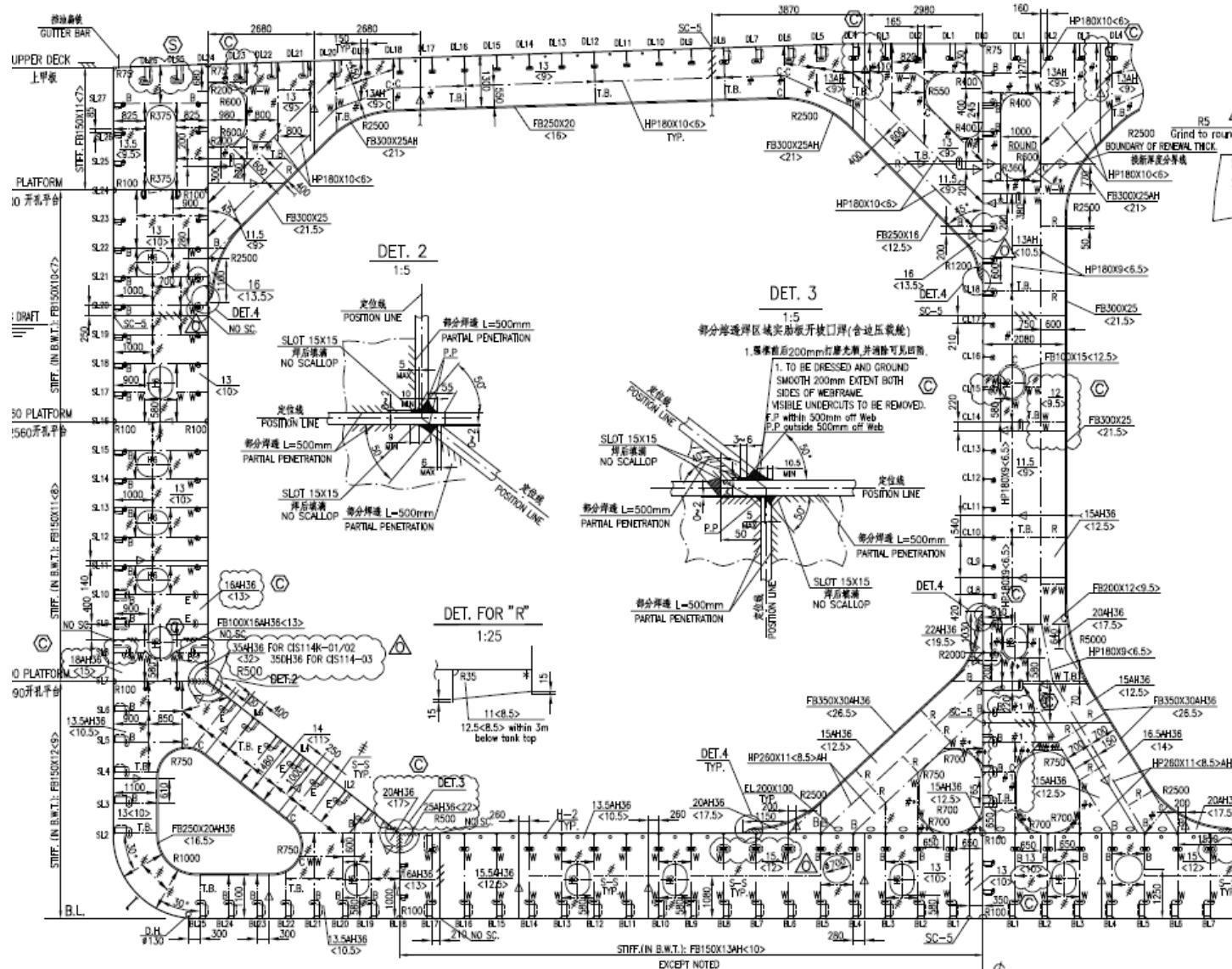
# Oil Tanker-Typical Web Frame

MARIC

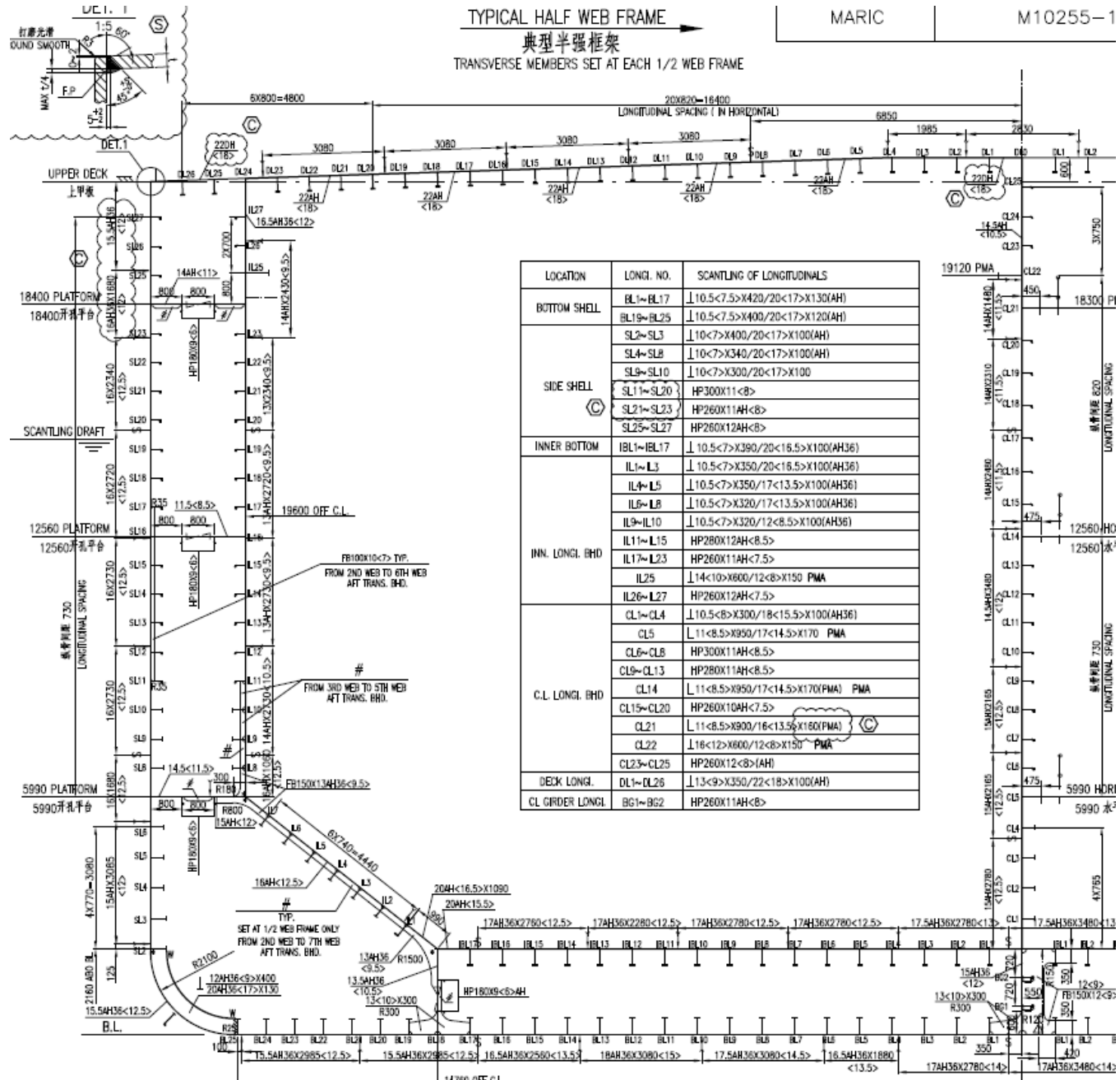
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TYPICAL WEB FRAME

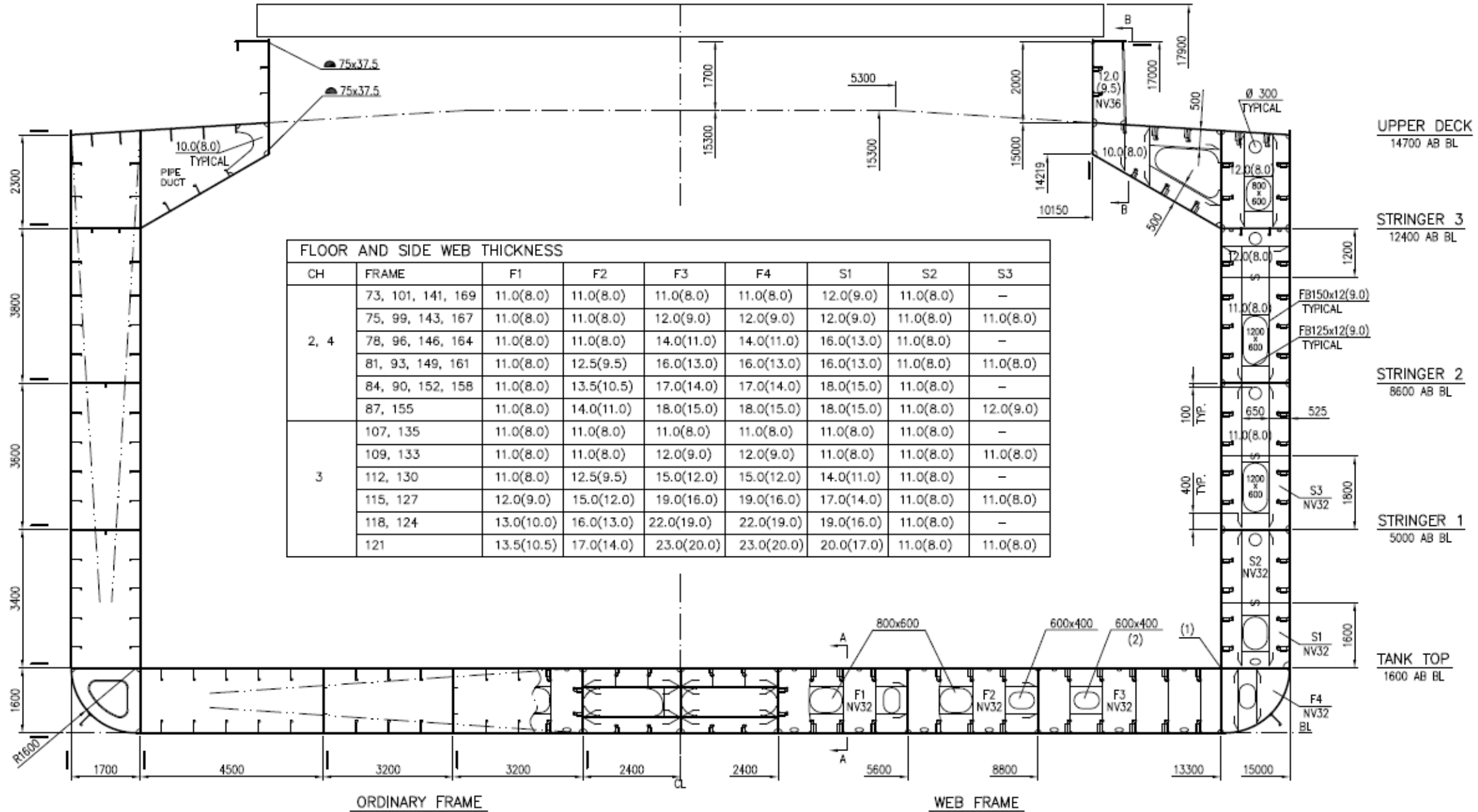
典型强框架



# Oil Tanker-Ordinary Frame

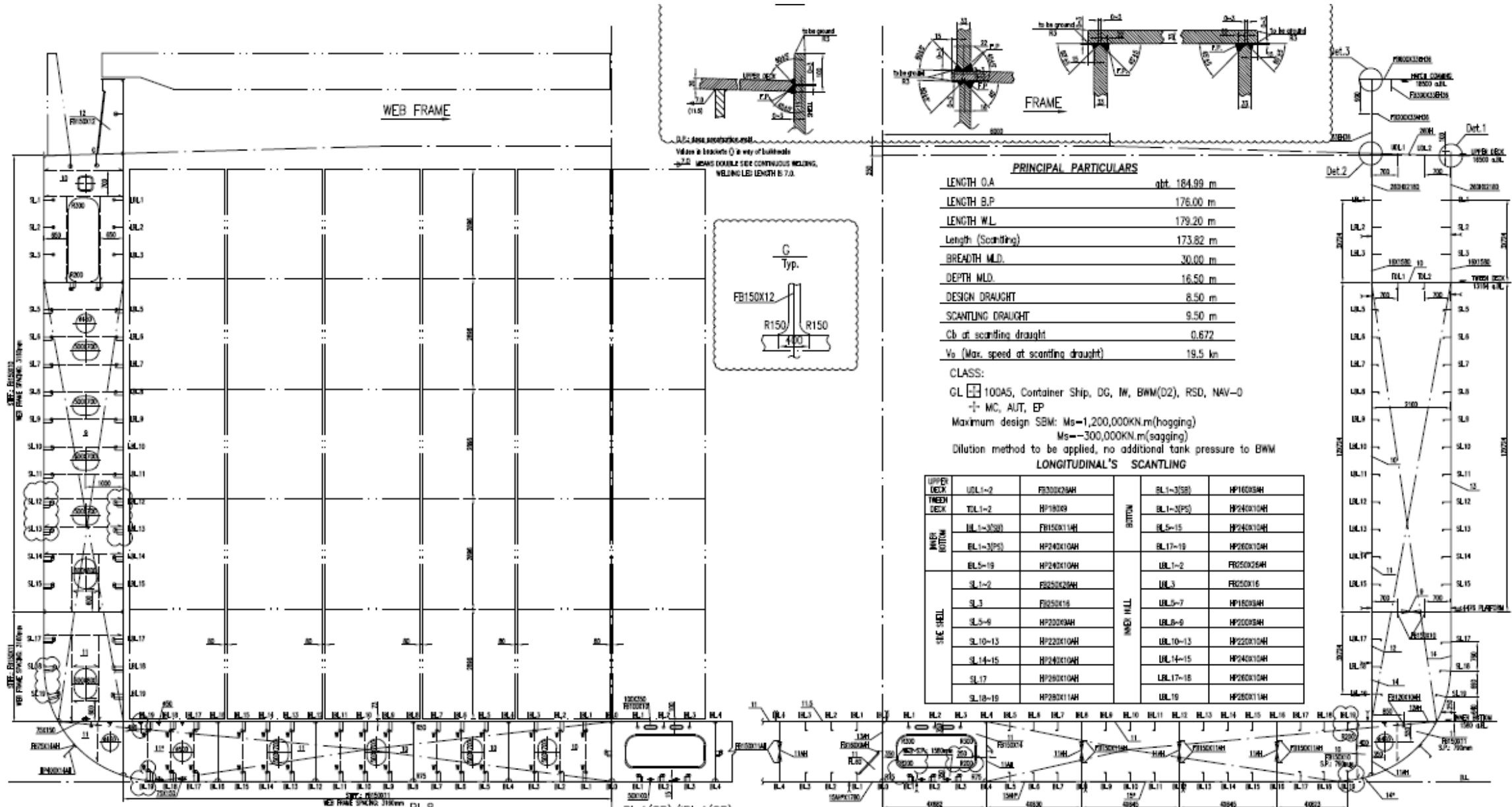


# Double Hull Bulk Carrier



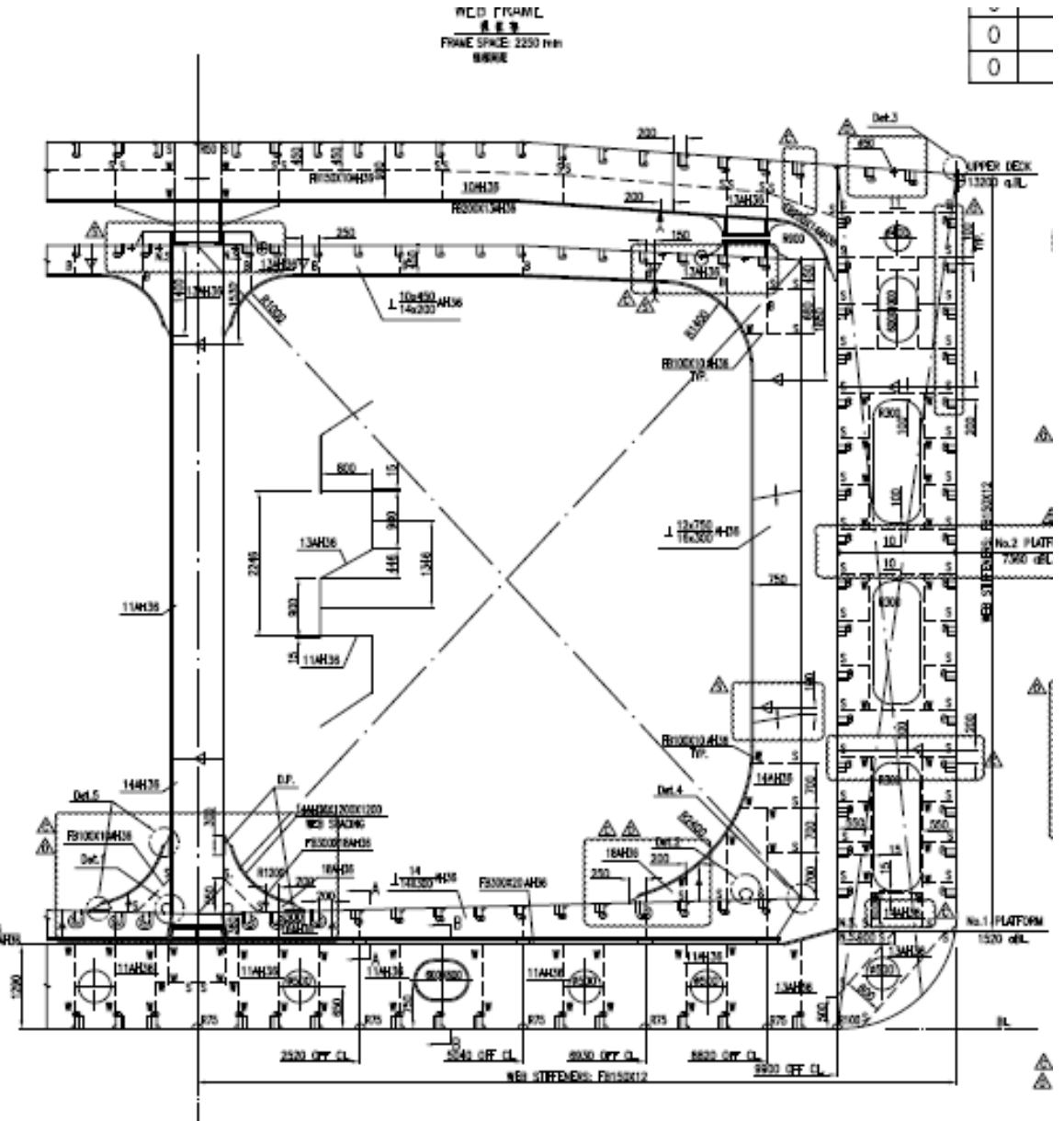
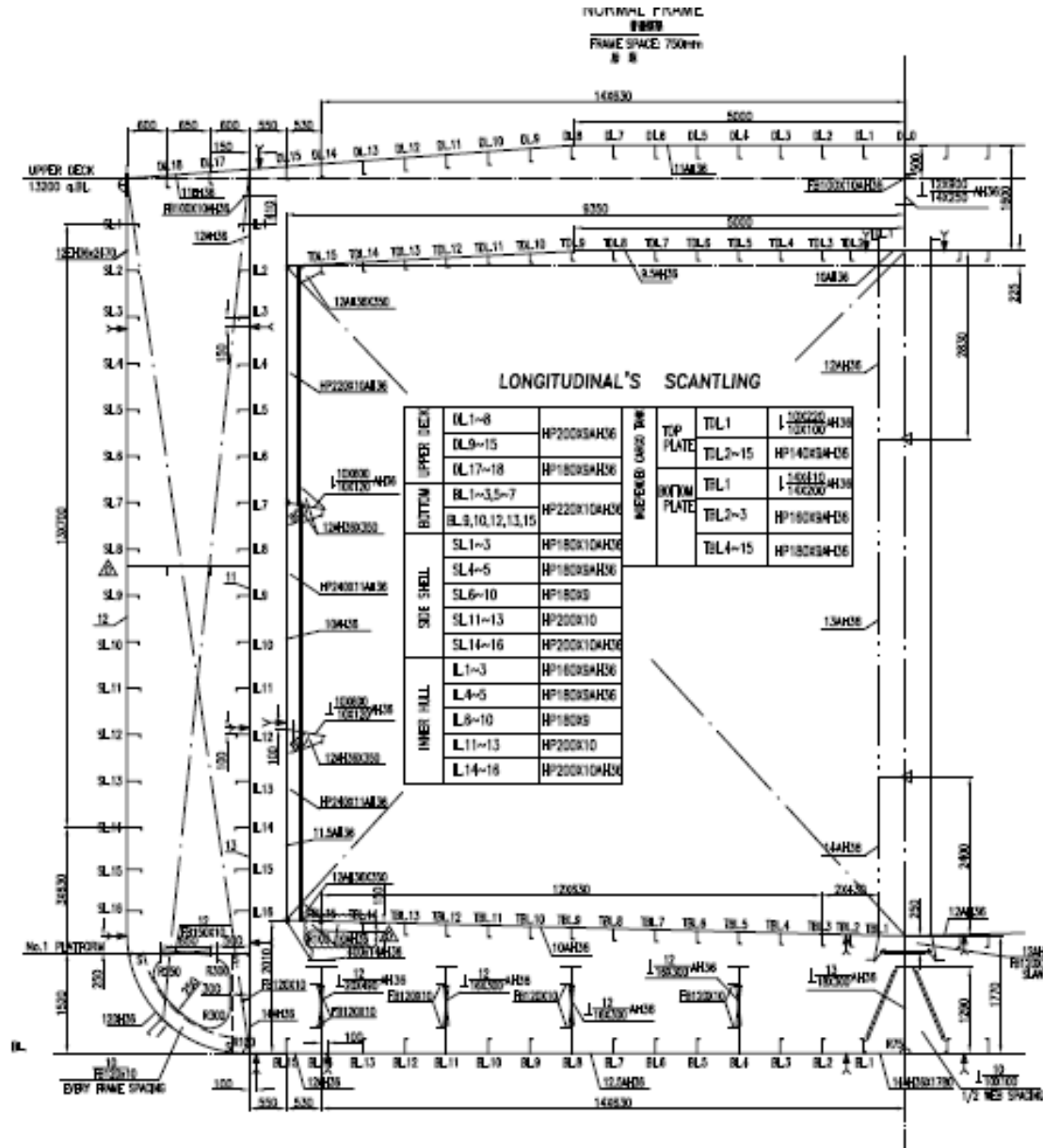


# Container Ship





# Asphalt Carrier



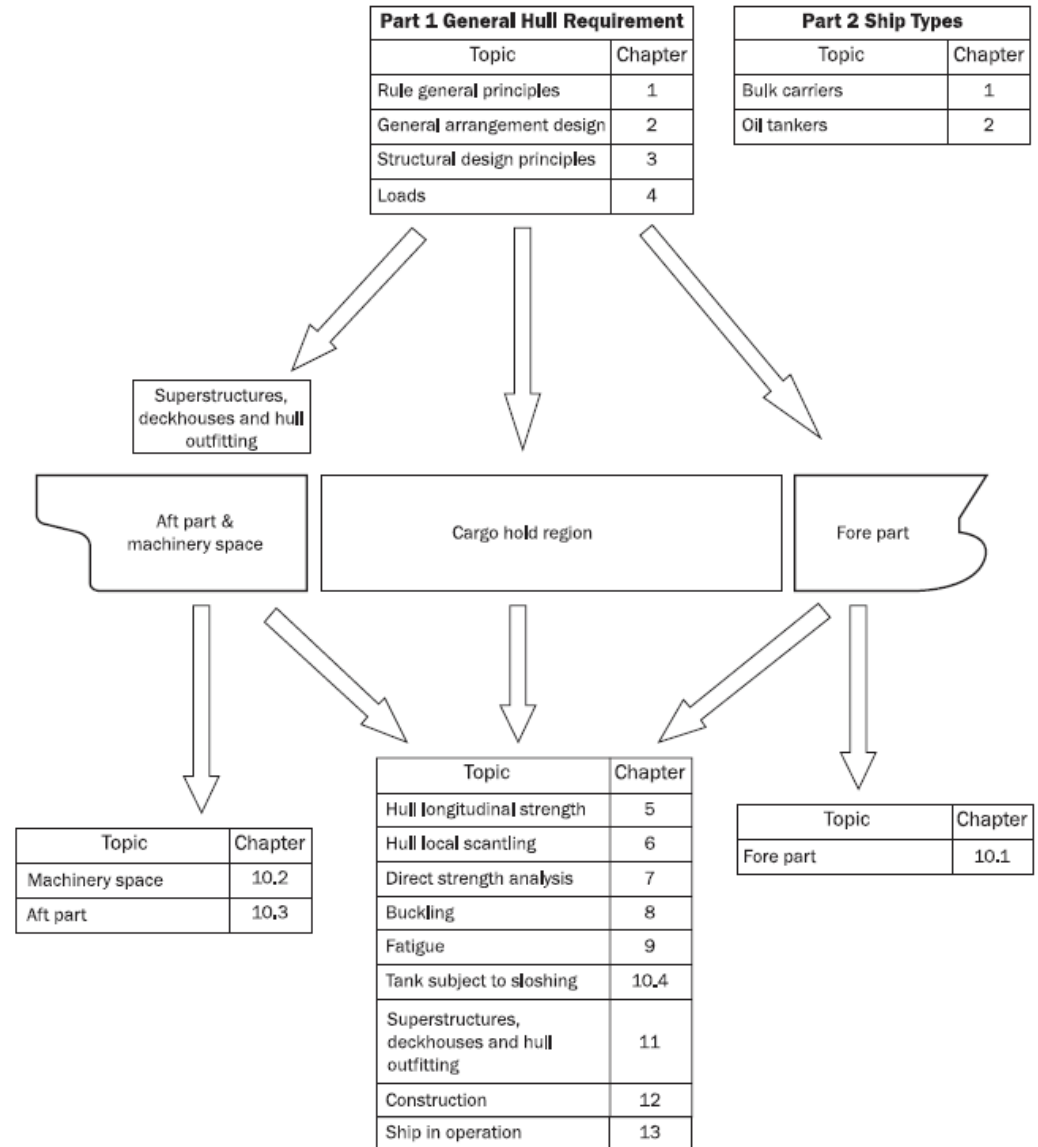
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## Πληροφορίες που περιλαμβάνονται στο Σχέδιο Μέσης Τομής

- Κύριες Διαστάσεις
- Χαρακτηρισμός κλάσης (Class Notation)
- Μηχανικές ιδιότητες χρησιμοποιούμενων χαλύβων (Steel Grades)
- Βύθισμα αντοχής (scantling draft)
- Αντοχή διπυθμένου
- Ροπή αντίστασης και ροπή αδράνειας της διατομής
- Μέγιστη καμπτική ροπή και τέμνουσα δύναμη σε ήρεμο νερό
- Διάρκεια ζωής έναντι κωπώσεως
- Πάχη αντικατάστασης ελασμάτων
- Κάτασκευαστικές λεπτομέρειες κρίσιμων περιοχών (critical areas)

# Έλεγχος αντοχής μεταλλικής κατασκευής με χρήση των CSR

Figure 4 : Application of the Rules



# Εξεταζόμενα σενάρια σχεδιαστικών φορτίσεων (Design Load Scenarios)

- Static Design Load Scenario (S)
- Static plus Dynamic Load Scenario (S+D)
- Impact Load Scenario (I)
- Sloshing Design Scenario (SL)
- Fatigue Design Load Scenario (F)
- Accidental Design Load Scenario (A)

# Οριακές καταστάσεις/ τρόποι αστοχίας (Limit States/Failure Modes)

- Serviceability Limit State (SLS)
- Ultimate Limit State (ULS)
- Fatigue Limit State (FLS)
- Accidental Limit State (ALS)

Possible failure modes to be considered	Limit states <sup>(1)</sup>			
	SLS	ULS	FLS	ALS
Yielding	Y	Y	-	Y
Plastic collapse	-	Y	-	Y
Buckling	Y	Y	-	Y
Rupture	-	Y	-	Y
Fatigue cracking	-	-	Y	-
Brittle fracture <sup>(2)</sup>	-	-	-	-

**(1)** "Y" indicates that the structural assessment is to be carried out.  
**(2)** Controlled by the material rule requirement of steel grade.

Yielding → Plastic deformations

Plastic collapse → Local permanent lateral deflection

Buckling → Instable Failure

Rupture → Braking due to large tensile stress (beyond the yield stress)

Brittle fracture → Depends on material, temperature and thickness

Fatigue cracking → Cracking due to fatigue degradation of the material

# Μέθοδοι σχεδίασης (Design Methods)

- Working Stress Design Method (WSD)

$$W_{stat} \leq \eta_1 R \quad \text{for condition A.}$$

$$W_{stat} + W_{dyn} \leq \eta_2 R \quad \text{for condition B.}$$

where:

$W_{stat}$  : Simultaneously occurring static loads (or load effects in terms of stresses).

$W_{dyn}$  : Simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components.

$R$  : Characteristic structural capacity (e.g. specified minimum yield stress or buckling capacity).

$\eta_i$  : Permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure.

Applicable in all cases  
except Ultimate Strength

- Partial Safety Factor Design Method (PSF)

$$\gamma_{stat-i} W_{stat} + \gamma_{dyn-i} W_{dyn} \leq \frac{R}{\gamma_R} \quad \text{for condition A.}$$

$$\gamma_{stat-2} W_{stat} + \gamma_{dyn-2} W_{dyn} \leq \frac{R}{\gamma_R} \quad \text{for condition B.}$$

where:

$\gamma_{stat-i}$  : Partial safety factor that accounts for the uncertainties related to static loads.

$\gamma_{dyn-i}$  : Partial safety factor that accounts for the uncertainties related to dynamic loads.

$\gamma_R$  : Partial safety factor that accounts for the uncertainties related to structural capacity.

Applicable to Ultimate  
Strength assessment

# Έλεγχος αντοχής

- Ο έλεγχος αντοχής με χρήση των CSR πραγματοποιείται σε δύο επίπεδα:
  1. Διαστασιολόγηση με βάση τις περιγραφικές απαιτήσεις (Prescriptive Requirements)
    - *(Η διαστασιολόγηση που προκύπτει με βάση τις περιγραφικές απαιτήσεις δεν μπορούν να μειωθούν με κανένα εναλλακτικό τρόπο υπολογισμού π.χ. απ' ευθείας υπολογισμό με αρχές της μηχανικής ή πεπερασμένα στοιχεία)*
  2. Επιβεβαίωση του αρχικού σχεδιασμού με εφαρμογή της μεθόδου των πεπερασμένων στοιχείων (Finite Elements)
    - *(Κατασκευή μοντέλου(-ων) τριών αμπαριών, Τοπική λεπτομερής ανάλυση)*

# Κριτήρια αποδοχής – περιγραφικές απαιτήσεις

Acceptance criteria	Plate panels and local support members <sup>(1)</sup>		Primary supporting members <sup>(1)</sup>		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-S AC-SD	Permissible stress: Ch 6, Sec 4 Ch 6, Sec 5	Control of stiffness and proportions: Ch 8, Sec 2	Permissible stress: Ch 6, Sec 6 Pt 2, Ch 1, Sec 4 Pt 2, Ch 2, Sec 3	Control of stiffness and proportions: Ch 8, Sec 1 Ch 8, Sec 2 Pillar buckling	Permissible stress: Ch 5, Sec 1	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]
AC-I	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	Plastic criteria: Ch 10, Sec 1, [3]	Control of stiffness and proportions: Ch 8, Sec 2 Ch 10, Sec 1, [3]	N/A	N/A

**(1)** Refer to Ch 10 for Other structures and to Ch 11 for Superstructure, deckhouses and hull outfitting

# Κριτήρια αποδοχής – Ανάλυση FEM

Acceptance criteria	Cargo hold analysis		Fine mesh analysis
	Yield	Buckling	Yield
AC-S AC-SD	Permissible stress: Ch 7, Sec 2, [5]	Allowable buckling utilisation factor: Ch 8, Sec 1, [3]	Permissible Von Mises stress: Ch 7, Sec 3, [6] Screening criteria: Ch 7, Sec 3, [3.3]

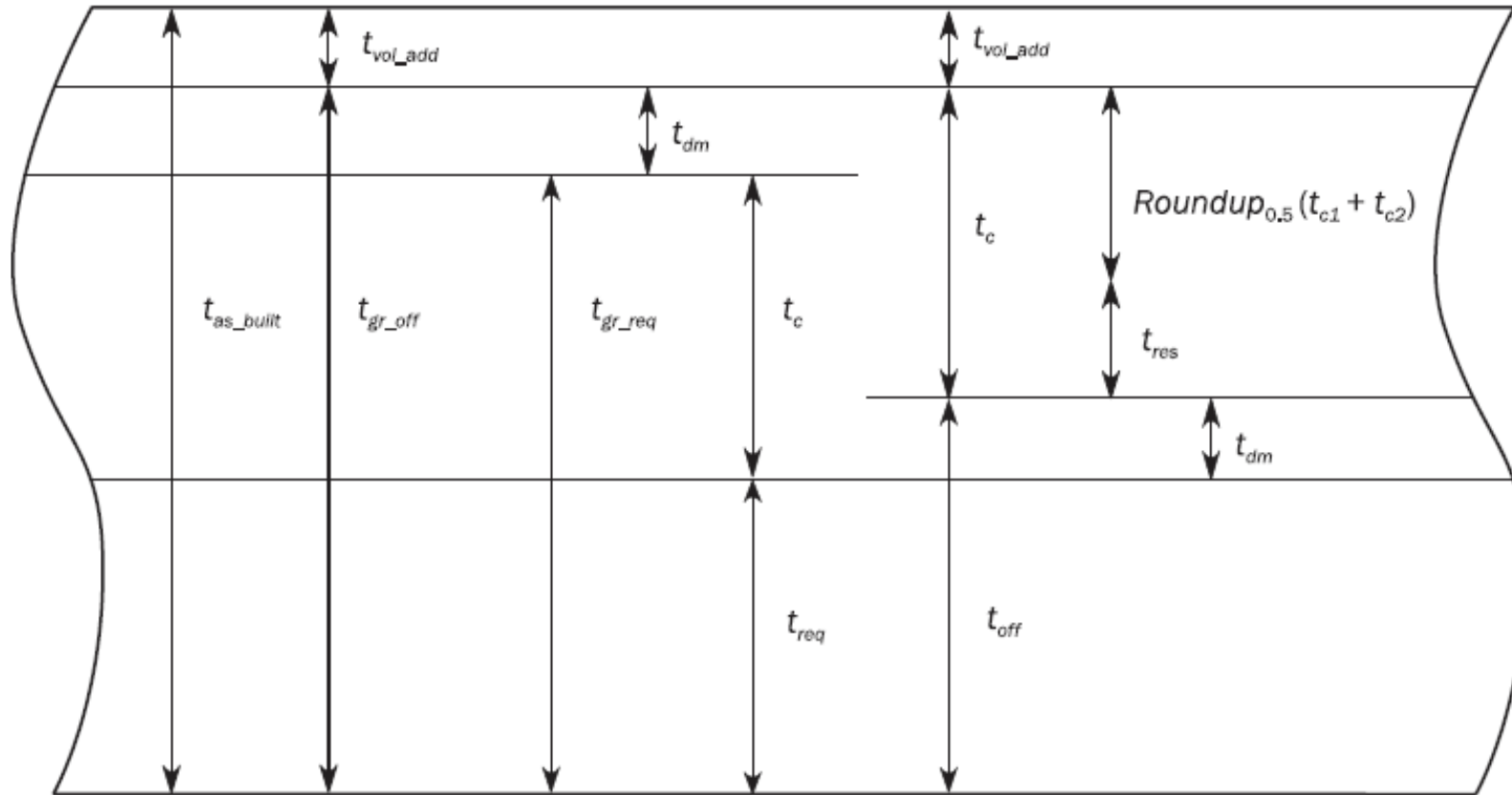
# Επιλογή ποιότητας χαλύβων (steel grades)

Structural member category		Material class/grade
Secondary	A1. Longitudinal bulkhead strakes, other than those belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	- Class I within 0.4 L amidships - Grade A/AH outside 0.4 L amidships
Primary	B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in topside tank	- Class II within 0.4 L amidships - Grade A/AH outside 0.4 L amidships
Special	C1. Sheer strake at strength deck <sup>(1)</sup> C2. Stringer plate in strength deck <sup>(1)</sup> C3. Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships <sup>(1)</sup>	- Class III within 0.4 L amidships - Class II outside 0.4 L amidships - Class I outside 0.6 L amidships
	C4. Strength deck plating at outboard corners of cargo hatch openings for ships with hatch opening configurations similar to those of container carriers	- Class III within 0.4 L amidships - Class II outside 0.4 L amidships - Class I outside 0.6 L amidships - Min. Class III within cargo hold region
	C5. Strength deck plating at corners of cargo hatch openings	- Class III within 0.6 L amidships - Class II within rest of cargo hold region
	C6. Bilge strake of ships with double bottom over the full breadth and with length less than 150 m	- Class II within 0.6 L amidships - Class I outside 0.6 L amidships
	C7. Bilge strake in other ships <sup>(1)</sup>	- Class III within 0.4 L amidships - Class II outside 0.4 L amidships - Class I outside 0.6 L amidships
	C8. Longitudinal hatch coamings of length greater than 0.15 L including coaming top plate and flange C9. End brackets and deckhouse transition of longitudinal cargo hatch coamings	- Class III within 0.4 L amidships - Class II outside 0.4 L amidships - Class I outside 0.6 L amidships - Not to be less than Grade D/DH
<sup>(1)</sup> Single strakes required to be of class III within 0.4L amidships are to have breadths not less than 800+5L, in mm, need not be greater than 1800 mm, unless limited by the geometry of the ship's design.		

Steel grades for plates with $t_{as\_built} \leq 100$ mm	$R_{eH}$ , specified minimum yield stress, in N/mm <sup>2</sup>	$R_m$ , specified tensile strength, in N/mm <sup>2</sup>
A-B-D-E	235	400 - 520
AH32-DH32-EH32-FH32	315	440 - 570
AH36-DH36-EH36-FH36	355	490 - 630
AH40-DH40-EH40-FH40	390	510 - 660

Class	I		II		III	
	MS	HT	MS	HT	MS	HT
As-built thickness, in mm						
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$40 < t \leq 50$	D	DH	E	EH	E	EH

# Προσέγγιση καθαρού πάχους



The net required thickness,  $t_{req}$ , is obtained by rounding the net thickness calculated according to the Rules to the nearest half millimeter.

# Προσέγγιση καθαρού πάχους

$t_{as\_built}$  : As-built thickness, in mm, taken as the actual thickness provided at the newbuilding stage.

$t_{gr\_off}$  : Gross offered thickness, in mm, as defined in [1.2.2].

$t_{gr\_req}$  : Gross required thickness, in mm, as defined in [1.2.1].

$t_{off}$  : Net offered thickness, in mm, as defined in [1.2.3].

$t_{dm}$  : Design production margin, in mm, taken as the thickness difference between offered gross thickness and required gross thickness (equal also to the difference between offered net and required net thickness) as a result of scantlings applied by the designer or builder to suit design or production situation. This difference in thickness is not to be considered as an additional corrosion margin.

$t_{req}$  : Net required thickness, in mm, as required in [1.3.1].

$t_{vol\_add}$  : Thickness for voluntary addition, in mm, taken as the thickness voluntarily added as the owner's extra margin or builder's extra margin for corrosion wastage in addition to  $t_c$ .

$t_{res}$  : Reserve thickness, in mm, taken equal to 0.5 mm.

$t_{c1}, t_{c2}$  : Corrosion addition on one side of the considered structural member, in mm, as defined in Ch 3, Sec 3, Table 1.

# Προσαυξήσεις λόγω διάβρωσης

Compartment type	Structural member		$t_{c1}$ or $t_{c2}$			
			Oil tankers	BC-A or BC-B ships with $L \geq 150$ m	Other BC ships	
Ballast water tank, bilge tank, drain storage tank, chain locker <sup>(1)</sup>	Face plate of PSM	Within 3m below top of tank <sup>(4)</sup>	2.0			
		Elsewhere	1.5			
	Other members <sup>(2)</sup> <sup>(3)</sup>	Within 3m below top of tank <sup>(4)</sup>	1.7			
		Elsewhere	1.2			
Cargo oil tank	Face plate of PSM	Within 3m below top of tank <sup>(4)</sup>	1.7	N/A		
		Elsewhere	1.4			
	Inner-bottom plating/bottom of tank		2.1			
	Other members	Within 3m below top of tank <sup>(4)</sup>	1.7			
		Elsewhere	1.0			
Dry bulk cargo hold <sup>(5)</sup>	Transverse bulkhead	Upper part <sup>(6)</sup>	2.4	1.0		
		Lower stool: sloping plate, vertical plate and top plate <sup>(7)</sup>	5.2	2.6		
		Other parts	3.0	1.5		
	Sloped plating of hopper tank, inner bottom plating		3.7	2.4		
	Other members	Upper part <sup>(6)</sup>	N/A			
		Webs and flanges of the upper end brackets of side frames of single side bulk carriers			1.8	1.0
		Webs and flanges of lower brackets of side frames of single side bulk carriers			2.2	1.2
Other parts		2.0			1.2	

Exposed to atmosphere	Weather deck plating	1.7
	Other members	1.0
Exposed to seawater	Shell plating between the minimum design ballast draught waterline and the scantling draught waterline	1.5
	Shell plating elsewhere	1.0
Fuel and lube oil tank		0.7
Fresh water tank		0.7
Void spaces <sup>(8)</sup>	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, inner surface of stool space not common with a dry bulk cargo hold or ballast cargo hold, etc.	0.7
Dry spaces	Internals of machinery spaces, pump room, store rooms, steering gear space, etc.	0.5

- (1)** 1.0 mm is to be added to the plate surface within 3m above the upper surface of the chain locker bottom.
- (2)** 0.5 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated cargo oil tanks. 0.3mm is to be added to each surface of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks or heated fuel/lube oil tanks. Heated oil tanks are defined as tanks arranged with any form of heating capability (the most common type is heating coils).
- (3)** 0.7 mm is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated fuel or lube oil tanks.
- (4)** Only applicable to cargo tanks and ballast tanks with weather deck as the tank top. The 3 m distance is measured vertically from and parallel to the top of the tank.
- (5)** Dry bulk cargo hold includes holds intended for the carriage of dry bulk cargoes, which may carry water ballast.
- (6)** Upper part of the cargo holds correspond to an area above the connection between the topside and the inner hull or side shell. If there is no topside, the upper part corresponds to the upper one third of the cargo hold height (where a plane bulkhead is fitted in way of a dry bulk cargo hold, the upper part of the bulkhead is defined in the same manner).
- (7)** If there is no lower stool fitted (i.e. engine room bulkhead or fore peak bulkhead) or if a plane bulkhead is fitted, then this corrosion addition should be applied up to a height level with the opposing bulkhead stool in that hold. In the case where a stool is not fitted on the opposing bulkhead, the vertical extent of this zone is to be from the inner bottom to a height level with the top of the adjacent hopper sloping plate, but need not be taken as more than 3 m.
- (8)** For the determination of the corrosion addition of the outer shell plating, the pipe tunnel is considered as for a water ballast tank.

# Αξιολόγηση κατασκευαστικής επάρκειας (Structural Assessment)

Structural Elements <sup>(1)</sup>		Yielding check	Buckling check	Ultimate strength check	Fatigue check
Local Structures	Stiffeners	Y	Y	Y <sup>(2)</sup>	Y
	Plating	Y	Y	Y <sup>(3)</sup>	-
Primary supporting members		Y	Y	Y <sup>(2)</sup>	Y
Hull girder		Y	Y <sup>(4)</sup>	Y	-
<p><b>(1)</b> "Y" indicates that the structural assessment is to be carried out.</p> <p><b>(2)</b> The ultimate strength check is included in the buckling check.</p> <p><b>(3)</b> The ultimate strength check of plating is included in the yielding check formula of plating.</p> <p><b>(4)</b> The buckling check of stiffeners and plating taking part in hull girder strength is performed against stress due to hull girder bending moment and hull girder shear force.</p>					

# Υπολογισμός φορτίσεων

- Static Loads

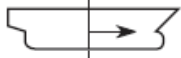
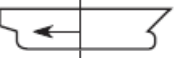
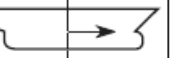
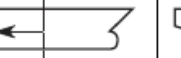

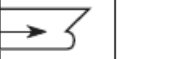









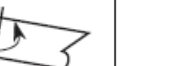
- Still water hull girder loads (Ch 4, Sec 4).
- External loads (Ch 4, Sec 5).
- Internal loads (Ch 4, Sec 6).

- Dynamic Loads

- Dynamic hull girder load components (Ch 4, Sec 4).
- External loads (Ch 4, Sec 5).
- Internal loads (Ch 4, Sec 6).

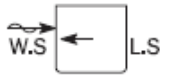
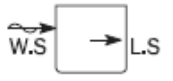


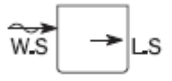
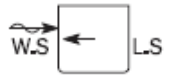
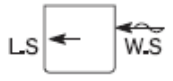
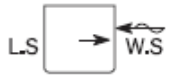
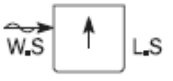
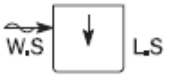

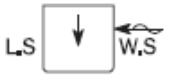
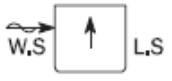
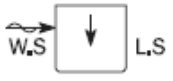
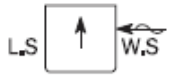
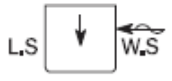












# Εξεταζόμενες περιπτώσεις δυναμικών φορτίσεων (dynamic load cases)

Table 1 : Ship responses for HSM, HSA and FSM load cases - Strength assessment

Loadcase	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
EDW	HSM		HSA		FSM	
Heading	Head		Head		Following	
Effect	Max. bending moment		Max. vertical acceleration		Max. bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	-	-	-	-	-	-
TM	-	-	-	-	-	-
Surge	To stern	To bow	To stern	To bow	To bow	To stern
$a_{surge}$						
Sway	-	-	-	-	-	-
$a_{sway}$	-	-	-	-	-	-
Heave	Down	Up	Down	Up	-	-
$a_{heave}$					-	-
Roll	-	-	-	-	-	-
$a_{roll}$	-	-	-	-	-	-
Pitch	Bow down	Bow up	Bow down	Bow up	Bow up	Bow down
$a_{pitch}$						

# Εξεταζόμενες περιπτώσεις δυναμικών φορτίσεων (dynamic load cases)

Table 2 : Ship responses for BSR and BSP load cases - Strength assessment

Load case	BSR-1P	BSR-2P	BSR-1S	BSR-2S	BSP-1P	BSP-2P	BSP-1S	BSP-2S
EDW	BSR		BSR		BSP		BSP	
Heading	Beam				Beam			
Effect	Max. roll				Max. pressure at waterline			
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile	Stbd tensile	Port tensile	Port tensile	Stbd tensile
TM	-	-	-	-	-	-	-	-
Surge	-	-	-	-	-	-	-	-
$a_{surge}$	-	-	-	-	-	-	-	-
Sway	To starboard	To portside	To portside	To starboard	To portside	To starboard	To starboard	To portside
$a_{sway}$								
Heave	Down	Up	Down	Up	Down	Up	Down	Up
$a_{heave}$								
Roll	Portside down	Portside up	Starboard down	Starboard up	Portside down	Portside up	Starboard down	Starboard up
$a_{roll}$								
Pitch	-	-	-	-	Bow down	Bow up	Bow down	Bow up
$a_{pitch}$	-	-	-	-				



# Συντελεστές συνδυαστικών φορτίσεων (Load Combination Factors)

**Table 4 : Load combination factors, LCFs for HSM, HSA and FSM load cases - Strength assessment**

Load component		LCF	HSM-1	HSM-2	HSA-1	HSA-2	FSM-1	FSM-2
Hull girder loads	$M_{WV}$	$C_{WV}$	-1	1	-0.7	0.7	$-0.4f_T - 0.6$	$0.4f_T + 0.6$
	$Q_{WV}$	$C_{QW}$	$-1.0f_{lp}$	$1.0f_{lp}$	$-0.6f_{lp}$	$0.6f_{lp}$	$-1.0f_{lp}$	$1.0f_{lp}$
	$M_{WH}$	$C_{WH}$	0	0	0	0	0	0
	$M_{WT}$	$C_{WT}$	0	0	0	0	0	0
Longitudinal accelerations	$a_{surge}$	$C_{XS}$	$0.3 - 0.2f_T$	$0.2f_T - 0.3$	0.2	-0.2	$0.2 - 0.4f_T$	$0.4f_T - 0.2$
	$a_{pitch-x}$	$C_{XP}$	-0.7	0.7	$-0.4f_T - 0.4$	$0.4f_T + 0.4$	0.15	-0.15
	$g\sin\varphi$	$C_{XG}$	0.6	-0.6	$0.4f_T + 0.4$	$-0.4f_T - 0.4$	-0.2	0.2
Transverse accelerations	$a_{sway}$	$C_{YS}$	0	0	0	0	0	0
	$a_{roll-y}$	$C_{YR}$	0	0	0	0	0	0
	$g\sin\theta$	$C_{YG}$	0	0	0	0	0	0
Vertical accelerations	$a_{heave}$	$C_{ZH}$	$0.5f_T - 0.15$	$0.15 - 0.5f_T$	$0.4f_T - 0.1$	$0.1 - 0.4f_T$	0	0
	$a_{roll-z}$	$C_{ZR}$	0	0	0	0	0	0
	$a_{pitch-z}$	$C_{ZP}$	-0.7	0.7	$-0.4f_T - 0.4$	$0.4f_T + 0.4$	0.15	-0.15

# Υπολογισμός πιέσεων για τον έλεγχο τοπικής αντοχής

Table 1 : Design load sets

Item	Design load set	Load component	Draught	Design load	Loading condition
External shell and exposed deck	SEA-1	$P_{ex}, P_D$	$T_{SC}$	S+D	Full Load condition <sup>(4)</sup>
	SEA-2	$P_{ex}$	$T_{SC}$	S	Harbour condition <sup>(2)</sup>
Water ballast tank (oil tanker and bulk carrier)	WB-1	$P_{in} - P_{ex}$ <sup>(3)</sup>	$T_{BAL}$	S+D	Normal ballast condition
	WB-2	$P_{in} - P_{ex}$ <sup>(3)</sup>	$T_{BAL}$	S+D	Normal ballast condition Water ballast exchange
	WB-3	$P_{in} - P_{ex}$ <sup>(3)</sup>	$0.25T_{SC}$	S	Harbour/test condition
Water ballast tank (bulk carrier) and bulk cargo hold assigned as ballast hold	WB-4	$P_{in} - P_{ex}$ <sup>(3)</sup>	$T_{BAL-H}$ <sup>(7)</sup>	S+D	Heavy ballast condition
	WB-5 <sup>(4)</sup>	$P_{in} - P_{ex}$ <sup>(3)</sup>	$T_{BAL-H}$ <sup>(7)</sup>	S+D	Heavy ballast condition Water ballast exchange
	WB-6 <sup>(5)</sup>	$P_{in}$	-	S	Harbour/test condition
Cargo oil tank	OT-1	$P_{in}$	$T_{SC}$	S+D	Full Load condition
	OT-2	$P_{in}$	$0.6T_{SC}$	S+D	Partial load condition
	OT-3	$P_{in}$	-	S	Harbour/Test condition

Item	Design load set	Load component	Draught	Design load	Loading condition
Bulk cargo hold	BC-1	$P_{in}$	$T_{SC}$	S+D	Homogeneous loading, fully filled
	BC-2	$P_{in}$	-	S	
	BC-3	$P_{in}$	$T_{SC}$	S+D	Homogeneous heavy cargo, partially filled (BC-A, B ships)
	BC-4	$P_{in}$	-	S	
	BC-5	$P_{in}$	$T_{SC}$	S+D	Alternate light cargo, fully filled (BC-A ships)
	BC-6	$P_{in}$	-	S	
	BC-7	$P_{in}$	$T_{SC}$	S+D	Alternate heavy cargo, partially filled (BC-A ships.)
	BC-8	$P_{in}$	-	S	
Other tanks (fuel oil tank, fresh water tank)	TK-1	$P_{in} - P_{ex}$ <sup>(3)</sup>	$T_{BAL}$	S+D	Normal ballast condition
	TK-2	$P_{in} - P_{ex}$ <sup>(3)</sup>	$0.25T_{SC}$	S	Harbour/test condition
Compartments not carrying liquids	FD-1 <sup>(6)</sup>	$P_{in}$	$T_{SC}$	S+D	Flooded condition
	FD-2 <sup>(6)</sup>	$P_{in}$	-	S	Flooded condition
Exposed deck, internal decks or platforms	DL-1 <sup>(8)</sup>	$P_{dl}, F_U$	$T_{SC}$	S+D	Full load condition
	DL-2 <sup>(8)</sup>	$P_{dl}, F_U$	-	S	Harbour condition

# Hull Girder Bending Assessment

$$\sigma_L \leq \sigma_{perm}$$

Table 2 : Normal stress,  $\sigma_L$

Operation	Normal stress, $\sigma_L$		
	At any point located below $Z_{VD}$	At bottom <sup>(1)</sup>	At deck <sup>(1)</sup>
Seagoing	$\sigma_L = \frac{M_{sw} + f_{\beta} M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + f_{\beta} M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw} + f_{\beta} M_{wv}}{Z_{D-n50}} 10^{-3}$
Harbour/sheltered water	$\sigma_L = \frac{M_{sw-p}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-p}}{Z_{D-n50}} 10^{-3}$
Flooded condition at sea for bulk carriers having a length $L$ of 150 m or above	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{A-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{B-n50}} 10^{-3}$	$\sigma_L = \frac{M_{sw-f} + M_{wv}}{Z_{D-n50}} 10^{-3}$

**(1)** The  $\sigma_L$  values at bottom and deck, correspond to the application of formula given for any point, calculated at equivalent deck line and at baseline.

Table 1 : Permissible hull girder bending stress

Operation	Design load	Permissible hull girder bending stress, $\sigma_{perm}$				
		$\frac{x}{L} \leq 0.1$	$0.1 < \frac{x}{L} < 0.3$	$0.3 \leq \frac{x}{L} \leq 0.7$	$0.7 < \frac{x}{L} < 0.9$	$\frac{x}{L} \geq 0.9$
Seagoing	(S+D)	140/k	Linear interpolation	190/k	Linear interpolation	140/k
Harbour/sheltered water	(S)	105/k	Linear interpolation	143/k	Linear interpolation	105/k
Flooded condition at sea for bulk carriers having a length $L$ of 150 m or above	(A:S+D)	140/k	Linear interpolation	190/k	Linear interpolation	140/k

Minimum required values:

$$\left\{ \begin{array}{l} Z_R = 0.9k C_w L^2 B (C_B + 0.7) 10^{-6} \\ I_{yR} = 2.7 C_w L^3 B (C_B + 0.7) 10^{-8} \end{array} \right\}$$

# Hull girder shear capacity

Shear Force calculation:

$$Q_R = \min_i \left( \frac{\tau_{i-perm} \cdot t_{i-n50}}{q_{vi}} \cdot 10^{-3} \right)$$

Permissible Shear Force:

- For seagoing operation:

$$|Q_{sw}| \leq Q_R - |f_{\beta} Q_{wv}|$$

- For harbour/sheltered water operation:

$$|Q_{sw-p}| \leq Q_R$$

- For flooded condition at sea of bulk carriers having a length  $L$  of 150 m or above:

$$|Q_{sw-f}| \leq Q_R - |Q_{wv}|$$

**Table 4 : Permissible hull girder shear stress**

Operation	Design load	Permissible hull girder shear, $\tau_{i-perm}$
Seagoing	(S+D)	120/k
Harbour/sheltered water	(S)	105/k
Flooded condition at sea of bulk carriers having a length $L$ of 150 m or above	(A:S+D)	120/k

# Έλεγχος μέσης τομής

## Hull Girder Analysis

Hull Girder Yielding Strength:  $(\sigma < \sigma_{al}, \tau < \tau_{al})$

Hull Girder Ultimate Strength :  $M = \gamma_S M_{sw-U} + \gamma_W f_\beta M_{wv}$   $M \leq \frac{M_U}{\gamma_R}$

Hull Girder Residual Strength:  $M_D = \gamma_{SD} M_{sw-D} + \gamma_{WD} M_{wv}$   $M_D \leq \frac{M_{UD}}{\gamma_{RD} \cdot C_{NA}}$

## Local strength Analysis

Plates:  $t = 0.0158 \alpha_p b \sqrt{\frac{|P|}{\chi C_a R_{eH}}}$

Stiffeners  $t_w = \frac{f_{shr} |P| s \ell_{shr}}{d_{shr} \chi C_t \tau_{eH}}$   $Z = \frac{|P| s \ell_{bdg}^2}{f_{bdg} \chi C_s R_{eH}}$

Primary supporting members  $Z_{n50} = 1000 \frac{|P| s \ell_{bdg}^2}{\chi f_{bdg} C_s R_{eH}}$   $A_{shr-n50} = 10 \frac{f_{shr} |P| s \ell_{shr}}{\chi C_t \tau_{eH}}$

# Ελάχιστες (εμπειρικές) απαιτήσεις

Table 1 : Minimum net thickness for plating

Element	Location	Area	Net thickness
Shell	Keel	-	$7.5 + 0.03 L_2$
	Bottom Side shell Bilge	Fore Part	$6.5 + 0.03 L_2$
		Machinery space Aft part	$7.0 + 0.03 L_2$
		Elsewhere	$5.5 + 0.03 L_2$
Breasthook		Fore part	6.5
Deck	Weather deck, strength deck, internal tank boundary	-	$4.5 + 0.02 L_2$
	Platform deck	Machinery space	$2.8 + 0.0067 s$
		Elsewhere	6.5
Inner bottom <sup>(1)</sup>	-	Machinery space	$6.6 + 0.024 L_2$
		Elsewhere	$5.5 + 0.03 L_2$
Longitudinal bulkheads of bulk carriers	Inner side, hopper tank top, top wing tank longitudinal bulkhead	Cargo hold region	$0.7 L_2^{3/2}$
Bulkheads	Internal tank boundary, Transverse/longitudinal watertight bulkhead	-	$4.5 + 0.02 L_2$
	Non-tight bulkhead, Wash bulkhead, Bulkheads between dry spaces.	-	$4.5 + 0.01 L_2$
	Pillar bulkheads in fore and aft peaks	-	7.5
Other members	Diaphragms in lower/upper stool	-	$5.0 + 0.015 L_2$
	Engine casing (in the cargo hold region)	Cargo hold region	5.5
	Engine casing (in way of accommodation)	Accommodation	4.0
	Other plates in general	-	$4.5 + 0.01 L_2$

(1) Applicable for both tight and non tight members

Table 2 : Minimum net thickness for stiffeners and tripping brackets

Element	Location	Net thickness
Stiffeners and attached end brackets	Watertight boundary	$3.5 + 0.015 L_2$
	Other structure	$3.0 + 0.015 L_2$
Cargo hold side frames webs of single side bulk carriers	Foremost hold <sup>(1)</sup>	$6.0 + 0.026 L$
	Other holds <sup>(1)</sup>	$5.2 + 0.023 L$
Tripping brackets		$5.0 + 0.015 L_2$

(1) L needs not to be taken greater than 200 m

Table 3 : Minimum net thickness for primary supporting members

Element	Location	Net thickness	
Double bottom centreline girder	Machinery space	$1.55 L_2^{1/3} + 3.5$	
	Elsewhere	$5.5 + 0.025 L_2$	
Other bottom girder	Machinery space	$1.7 L_2^{1/3} + 1.0$	
	Fore part of ships with $L \geq 150 m$	$0.7 L_2^{3/2}$	
	Elsewhere and fore part of ships with $L < 150 m$	$5.5 + 0.02 L_2$	
Girders bounding a duct keel	Machinery space	$0.8 L_2^{3/2} + 2.5$	
Bottom floor	Machinery space	$1.7 L_2^{1/3} + 1.0$	
	Fore part	$0.7 L_2^{3/2}$	
	Elsewhere	$0.6 L_2^{3/2}$	
Aft peak floor	-	$0.7 L_2^{3/2}$	
Other primary supporting member	Aft part / fore part	$0.7 L_2^{3/2}$	
	Elsewhere	In oil cargo tanks	$5.5 + 0.015 L_2$
		For other cases	$0.6 L_2^{3/2}$

# Design sea pressures

- Static Load Scenario:  $P_{ex} = P_s$
- Static plus Dynamic Load Scenario:  $P_{ex} = P_s + P_w$  |
  - Formulae are included in the Rules for  $P_w$  for all Load Cases (HSM, HAS, FSM etc)

Primary supporting members PSM	Members of the beam, girder or stringer type which provide the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads.
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