PRELIMINARY STRUCTURAL ARRANGEMENT OF A BALTIC 61

STRUCTURAL DESIGN FOR PRODUCTION

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Date: *11 - Jan - 19*

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1. Introduction

The following document shows the work done to stablish the preliminary structural arrangement of a Baltic 61 sailing yacht. The yacht is a bespoke 61 foot light weight cruiser racer, classified under the class A on the ISO 12215. The structural arrangement is built with advanced composites (GRP), employing sandwich construction and carbon/epoxy laminates.

2. Assumptions

Following assumptions have been made to conclude with the following proposed structural arrangement:

- Maximum GZ at 60 degrees of heel assumed to be 1 metre.
- Based on the boat specifications, the keel type has been assumed to be an axial ballasted keel with a top flange.
- The floors are assumed to carry 100% of the transverse bending moment and forces, therefore, nothing is carried by any longitudinal girders except, where relevant when connecting these floors . In order to apply this condition, the total girder stiffness is required by the ISO to be at least 50% greater than the total floor stiffness.
- If one of the floors is much stiffer than the other floors, it has the risk of attracting greater loads. In order to prevent this from occurring, all the floors are assumed to share the same dimensions and stiffness properties.

3. Structural Arrangement

Interior structure has been designed taking into consideration the yacht interior GA, so the structure is built around the given interior arrangement, as shown in Appendix 1. For that, the stiffener locations and spacings were decide based on the interior features and the boundaries set by the frames or other components. The main girders run parallel to the centerline at an offset distance and provide the main longitudinal strength of the internal structure. The girders also connect the keel floors and the mast step floors. These longitudinal stiffeners run from the forward bulkhead to the mainsheet support frame.

The mast step is supported by two transversely running floors, connected to the main girders to obtain a stiff and stable base for the mast to be placed. The monolithic carbon fibre is employed to fill the crown of the mast step girder, so the T-base of the mast is bolted. Also, a monolithic carbon fibre plate is employed instead of a stainless steel plate, as there would be high risks of the epoxy corroding the stainless steel (Symbiosisonlinepublishing.com, 2019).

The mast bulkhead is built from a sandwich laminate composed by a core and carbon fibre reinforcement at each side. Note that zones were the longitudinal stiffeners are connected with the bulkhead require a thicker laminate reinforcement and a higher density core. This component is reinforced with unidirectional reinforcement to connect the point load at the chain plates; where the shrouds are connected to the structure, with the main structure at the bottom. Also, compression loads from the shrouds at the top of the bulkhead are considered, so a unidirectional reinforcement is placed to take the compression loads.

4. Loading Conditions

The scantling requirements were assessed with the software Hullscant to determine the local strength of the hull panels and stiffeners against the ISO 12215-5, with the aim of achieving an overall structural strength that ensures watertight and weathertight integrity of the craft. However, the local loads considered by the ISO 12215-5 are only water pressure loads, which does not cover all the loading conditions for this yacht. Only the most critical panel were evaluated as the those will show the greater requirements, so it can be assumed that the non-evaluated panels do comply with the ISO12215-5 with a greater compliance ratio than the evaluated panels. Evaluated panels are shown in Appendix 2, and Hullscant results on Appendix 4.

In order to cover a greater range of loadcases and ensure the strength of the yacht, the structural efficiency of all elements of the keel and its connection to the craft was assessed with the ISO 12215-9. This part of the ISO 12215 evaluates the keel member under a series of loadcases. For this specific yacht only loadcases 1 (Fixed keel at 90° knockdown), 3 (Keelboat vertical pounding) and 4 (Keelboat longitudinal impact) were considered the keel members structural integrity assessment. This loadcases estimate the bending moment (M) and shear force (SF) loads that the floors would be subjected to. The loads from ISO 12215-9 were compared to the maximum M and SF values that each floor can support, obtained by laminate stack analysis for FRP with the ISO12215-5, Annex C. Results from the ISO 12215-9 can be found on Appendix 3.

5. Conclusion

The structural arrangement of the yacht is not fully completed as more load conditions should be evaluated, and also the deck requirements remain to be assessed. Also, the operational envelope of the yacht will suppose a great assessment point to the structural arrangement. All in all, the proposed structure complies with the ISO 12215 parts 5 and 9, which require the greater requirements for this type of sailing yacht.

6. Bibliography

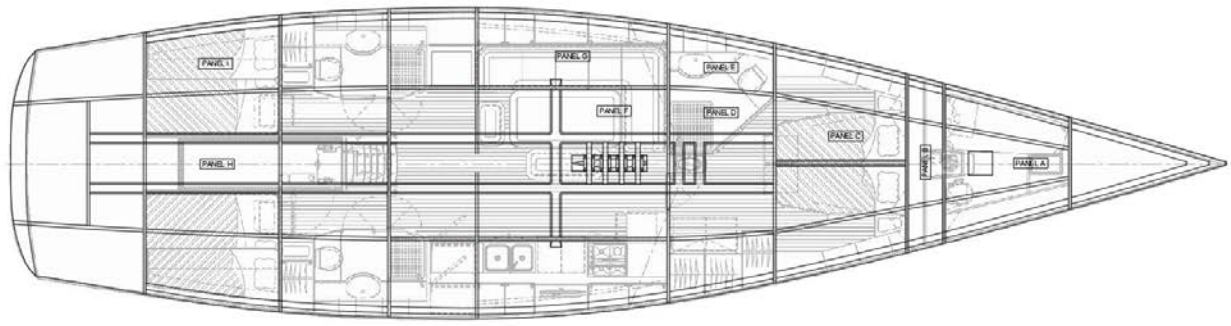
REF 1. Gurit - Guide to composites. (n.d.). 1st ed.

REF 2. West System technical manual. (1981). Bay City, Mich.: Gougeon.

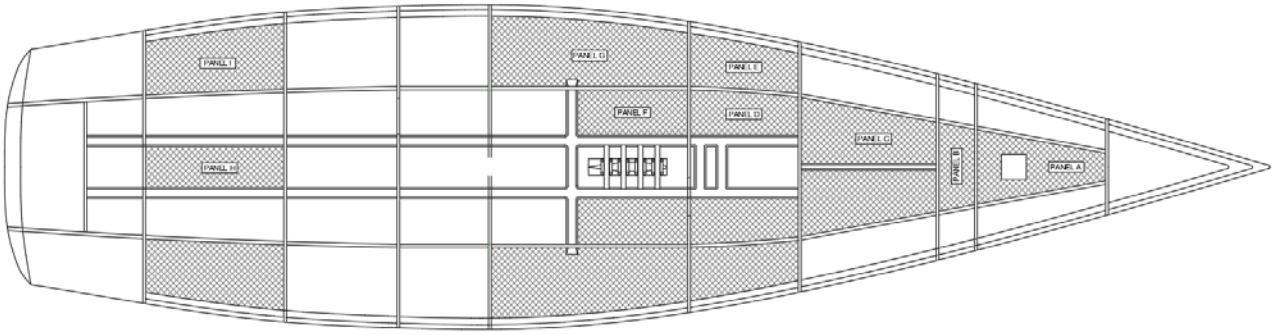
REF 3. Sano, T., Srivatsan, T. and Peretti, M. (n.d.). *Advanced composites for aerospace, marine, and land applications*.

7. Appendix

Appendix 1. Interior Structure



Appendix 2. Hullscant Evaluated Panels



Appendix 3. ISO 12215-9 Results

FLOORS DEFINITION					
Floor No. →	1	2	3	4	Unit
Item ↓					
L_{Fl}	3.4	3.4	3.4	3.4	m
b_l	0.4	0.4	0.4	0.4	
EI_l	9.07E+04	9.07E+04	9.07E+04	9.07E+04	N·mm^2
b_C	50.00	50.00	50.00	50.00	mm
b_b	60.00	60.00	60.00	60.00	
h	90.00	90.00	90.00	90.00	
w_b	50.00	50.00	50.00	50.00	
t_w	4.36	4.36	4.36	4.36	
t_f	2.47	2.47	2.47	2.47	
x_l	0.26129	0.50768	0.75209	0.99848	m

GIRDERS DEFINITION			
Girder No. →	1	2	Unit
Item ↓			
L_{Gl}	5	5	m
EI_l	1.78E+06	1.78E+06	N·mm^2

Floor No.	Fixity		k_{EF}	K_{FLOOR}	β_l	k_β	F_{FLOOR}	$(x_l \cdot K_{FLOOR})$	$(K_{FLOOR}) \cdot (x_R - x_l)$	$(K_{FLOOR}) \cdot (x_R - x_l)^2$
1	Floors supported by girders	FF	4	9234.3	0.12	1	9234.3	2.41E+03	3.40E+03	1.25E+03
2	Floors supported by girders	FF	4	9234.3	0.12	1	9234.3	4.69E+03	1.13E+03	1.38E+02
3	Floors supported by girders	FF	4	9234.3	0.12	1	9234.3	6.94E+03	-1.13E+03	1.38E+02
4	Floors supported by girders	FF	4	9234.3	0.12	1	9234.3	9.22E+03	-3.40E+03	1.25E+03
			∑=	36937.0		∑=	36937.0	2.33E+04	∑=	2.78E+03

K_{GFSR}	3.08	Effective floors
x_R	0.63	m
λ	0.49	-
PG	1.06	

Girder No.	$J_{DESCRIPTION}$	J_{VALUE}	Fixity	k_{EF}	K_{GIRDER}
1	Pair of near-centerline side girders	2	FF	4	56871.0
2	Pair of near-centerline side girders	2	FF	4	56871.0
				∑=	113742.0

LC No.	Item	Value	Unit
1	F_1	58958.1	N
	$M_{1.1}$	70749.7	N·m
	$M_{1.2}$	94333.0	
3	F_3	100454.4	N
4	F_4	120545.3	N
	$M_{4.1}$	358019.5	N·m
	$M_{4.2}$	406237.6	

Floor No.	M_i LC - 1	SF A/D LC - 1	SF B/C LC - 1	M A/D LC - 1	M B/C LC - 1	F_{vi} LC - 3	SF A/D LC - 3	SF B/C LC - 3	M A/D LC - 3	M B/C LC - 3	F_{viF4} LC - 4	SF A/D LC - 4	SF B/C LC - 4	M A/D LC - 4	M B/C LC - 4	Max. SF LC - 4	Max. M LC - 4
1	23583.2	10354.4	-47447.6	5810.9	9679.3	30136.32	15068.16	15068.16	12623.5	9918.5	496488.0	248244.0	248244.0	207968.9	163404.1	248244.0	207968.9
2	23583.2	10354.4	-47447.6	5810.9	9679.3	30136.32	15068.16	15068.16	12623.5	9918.5	164607.0	82303.5	82303.5	68950.6	54175.5	82303.5	68950.6
3	23583.2	10354.4	-47447.6	5810.9	9679.3	30136.32	15068.16	15068.16	12623.5	9918.5	-164607.0	-82303.5	-82303.5	-68950.6	-54175.5	15068.2	12623.5
4	23583.2	10354.4	-47447.6	5810.9	9679.3	30136.32	15068.16	15068.16	12623.5	9918.5	-496488.0	-248244.0	-248244.0	-207968.9	-163404.1	15068.2	12623.5
																248244.0	207968.9
															Offered	113499.4	24276.1
															Validation	146%	112%

ISO Scantling Report

Filename: C:\Users\2fueri65\Downloads\Baltic 61 - Hullscant Evaluation - 2.bst
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Contents

Boat Particulars

Craft Type	Sailing
Design Category	A, Ocean
Composite Evaluation Level	EL-c, default data with 0.8 factor, ISO fibre content by mass
Displacement, m_{LDC}	16250.0 kg
Length of Hull, L_H	18.450 metres
Waterline Length, L_{WL}	16.765 metres
Waterline Beam, B_{WL}	3.800 metres
Canoe Body Depth, T_C	0.600 metres

General Calculations

Design Category Factor, k_{DC}	1.000
Base Bottom Pressure, $P_{BS\ BASE}$	86.634 kN/m^2
Base Deck Pressure, $P_{DS\ BASE}$	24.262 kN/m^2

Panel Geometry and Calculations

Label	Dimensions and Location							Calculations to ISO Standard					
	Length mm	Width mm	Aspect Ratio	Longitudinal Position metres	Location	z metres	Curvature mm	k_L	k_{AR}	k_2	k_3	k_z	Design Pressure kN/m^2
Panel A	1620	683	2.372	8.250	Bottom	--	25	0.910	0.538	0.500	0.028	--	42.4
Panel B	1564	626	2.500	9.952	Bottom	--	25	0.995	0.566	0.500	0.028	--	48.7
Panel C	1957	808	2.421	11.615	Bottom	--	15	1.000	0.500	0.500	0.028	--	43.3
Panel D	1564	675	2.316	9.951	Bottom & Side	--	15	0.995	0.547	0.500	0.028	0.000	23.5
Panel E	1277	519	2.462	12.945	Bottom	--	15	1.000	0.651	0.500	0.028	--	56.4
Panel F	2847	977	2.913	7.577	Bottom & Side	--	25	0.877	0.426	0.500	0.028	0.000	23.5
Panel G	2004	857	2.337	2.208	Bottom & Side	--	25	0.611	0.452	0.500	0.028	0.000	23.5
Panel H	2003	635	3.154	2.208	Bottom	--	0	0.611	0.559	0.500	0.028	--	32.1
Panel I	1858	733	2.533	14.200	Bottom	--	25	1.000	0.501	0.500	0.028	--	43.4
Panel J	2847	800	3.559	7.577	Side	1.500	25	0.877	0.469	0.500	0.028	0.267	23.5
Panel K	1957	815	2.402	11.615	Side	1.500	15	1.000	0.500	0.500	0.028	0.267	23.5
Panel L	2847	600	4.746	7.577	Side	1.500	25	0.877	0.583	0.500	0.028	0.867	40.1

Panel Results

Label	Requirements						Offered							Results						
	M_{db} N.mm/mm	M_{dl} N.mm/mm	EI_b N.m^2/mm	w_{os} kg/m^2	w_{is} kg/m^2	Shear Force N/mm	Label	M_{db} N.mm/mm	M_{dl} N.mm/mm	EI_b N.m^2/mm	w_{os} kg/m^2	w_{is} kg/m^2	Shear Force N/mm	b Min Ply No. and Stress Ratio	l Min Ply No. and Stress Ratio	EI_b Ratio	w_{os} Ratio	w_{is} Ratio	Shear Force Ratio	Plating Comply?	Core Comply?
Panel A	1577.8	1034.4	1.736	1.279	0.895	13.7	Hull - Bottom	3427.4	3427.4	23.727	1.495	1.495	16.9	9, 2.172	9, 3.313	13.667	1.169	1.670	1.234	yes	yes
Panel B	1485.9	991.8	1.480	1.279	0.895	14.4	Hull - Bottom	3427.4	3427.4	23.727	1.495	1.495	16.9	9, 2.307	9, 3.456	16.030	1.169	1.670	1.169	yes	yes
Panel C	2359.1	1476.7	3.141	1.279	0.895	16.8	Hull - Bottom - "A"	3453.0	3453.0	26.721	2.095	1.495	24.4	10, 1.464	10, 2.338	8.507	1.639	1.670	1.457	yes	yes
Panel D	891.6	560.5	0.991	1.279	0.895	7.5	Hull - Bottom	3427.4	3427.4	23.727	1.495	1.495	16.9	9, 3.844	9, 6.115	23.932	1.169	1.670	2.240	yes	yes
Panel E	1265.6	790.9	1.081	1.279	0.895	14.0	Hull - Bottom - "A"	3453.0	3453.0	26.721	2.095	1.495	24.4	10, 2.728	10, 4.366	24.709	1.639	1.670	1.739	yes	yes
Panel F	1868.4	1148.3	3.008	1.279	0.895	11.3	Hull - Bottom	3427.4	3427.4	23.727	1.495	1.495	16.9	9, 1.834	9, 2.985	7.889	1.169	1.670	1.496	yes	yes
Panel G	1437.5	902.9	2.030	1.279	0.895	9.6	Hull - Bottom	3427.4	3427.4	23.727	1.495	1.495	16.9	9, 2.384	9, 3.796	11.690	1.169	1.670	1.761	yes	yes
Panel H	1077.1	656.8	1.127	1.279	0.895	10.1	Hull - Bottom	3427.4	3427.4	23.727	1.495	1.495	16.9	9, 3.182	9, 5.219	21.063	1.169	1.670	1.671	yes	yes
Panel I	1895.2	1213.6	2.258	1.279	0.895	15.3	Hull - Bottom - "A"	3453.0	3453.0	26.721	2.095	1.495	24.4	10, 1.822	10, 2.845	11.831	1.639	1.670	1.601	yes	yes
Panel J	1241.6	754.1	1.629	1.151	0.805	9.4	Hull - Topsides	2602.1	2602.1	13.747	1.495	1.495	12.8	8, 2.096	8, 3.451	8.437	1.299	1.856	1.370	yes	yes
Panel K	1299.2	813.9	1.744	1.151	0.805	9.1	Hull - Topsides - "A"	2602.1	2602.1	13.747	1.495	1.495	18.4	8, 2.003	8, 3.197	7.883	1.299	1.856	2.015	yes	yes
Panel L	1110.5	703.5	1.055	1.151	0.805	11.8	Hull - Topsides	2602.1	2602.1	13.747	1.495	1.495	12.8	8, 2.343	8, 3.699	13.031	1.299	1.856	1.089	yes	yes

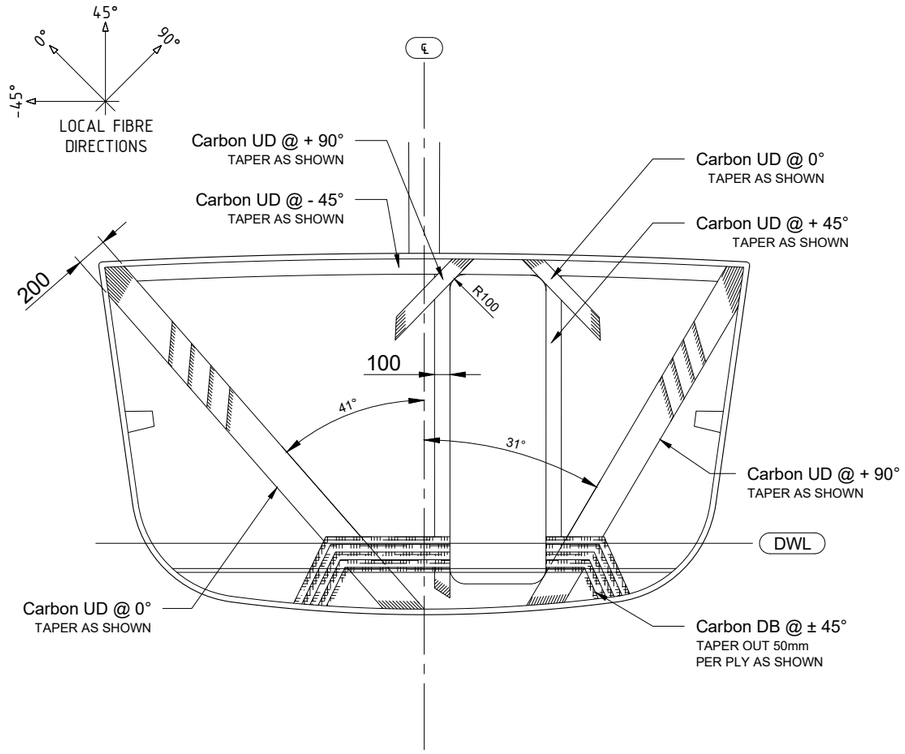
Stiffeners

Label	Dimensions and Location						Calculations to ISO Standard					Requirements				Offered					Results				
	Length mm	Spacing mm	Longitudinal Position metres	Location	z metres	Curvature mm	k_L	k_{AR}	z	k_z	Design Pressure kN/m^2	Bending Moment N.m	Shear Force N	EI N.m^2	t_w mm	Label	Bending Moment N.m	Shear Force N	EI N.m^2	t_w mm	Bending Moment Ratio	Shear Force Ratio	EI Ratio	t_w Ratio	Comply?
Floor A	635	502	7.889	Bottom	--	10.000	0.892	0.527	--	--	40.7	686.6	6490.4	272.2	2.3	Stringers	4205.4	58910.7	122526.1	5.9	6.125	9.077	450.170	2.608	yes
Floor B	635	246	8.135	Bottom	--	10.000	0.905	0.653	--	--	51.2	421.9	3987.6	167.2	1.8	Stringers	4205.4	58910.7	122526.1	5.9	9.969	14.773	732.713	3.327	yes
Floor C	635	246	8.380	Bottom	--	10.000	0.917	0.653	--	--	51.8	427.5	4041.2	169.5	1.8	Stringers	4205.4	58910.7	122526.1	5.9	9.837	14.578	722.999	3.305	yes
Floor D	635	246	8.626	Bottom	--	10.000	0.929	0.653	--	--	52.5	433.2	4095.0	171.7	1.8	Stringers	4205.4	58910.7	122526.1	5.9	9.707	14.386	713.500	3.283	yes
Girder A	1677	737	8.226	Bottom	--	10.000	0.909	0.267	--	--	32.1	5534.3	19808.7	5793.7	5.1	Girders	17646.5	154969.6	837114.5	7.4	3.189	7.823	144.487	1.453	yes
Stringer A	2847	1036	7.577	Bottom	--	100.000	0.877	0.250	--	--	32.1	22041.1	47271.8	38838.6	11.2	L-Stringer	23335.9	77009.0	2108455.0	2.9	1.059	1.629	54.288	0.260	yes with warning: web shear buckling likely
Floor FWD	1957	808	11.615	Bottom	--	0.000	1.000	0.250	--	--	32.1	8268.9	25359.0	10103.0	3.5	Reinforced Stringers	8549.3	134968.3	242306.6	11.9	1.034	5.322	23.984	3.424	yes
TopSide - Stringer A	2847	990	7.577	Side	1.500	10.000	0.877	0.250	1.500	0.600	23.5	15688.7	33076.9	27882.6	4.3	Topside Stringers	15747.6	160137.0	580306.8	11.9	1.004	4.841	20.813	2.771	yes

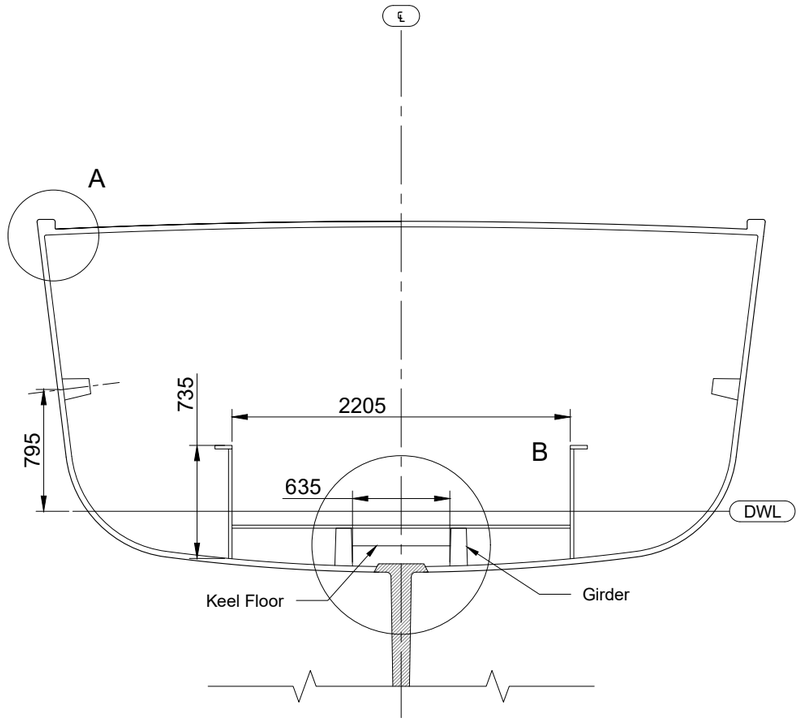
Report produced using Wolfson Unit M.T.I.A. HullScant - Hull Scantlings 12215.

Incorporating: International Standard - Hull construction - Scantlings - Part 5: Design pressures for monohulls, design stresses, scantling determination. ISO 12215-5:2008/Amd 1:2014 2014-09-30

MIDSHIPS SECTION @ SECTION A



MIDSHIPS SECTION @ SECTION B



DETAIL A - HULL AND DECK JOINT

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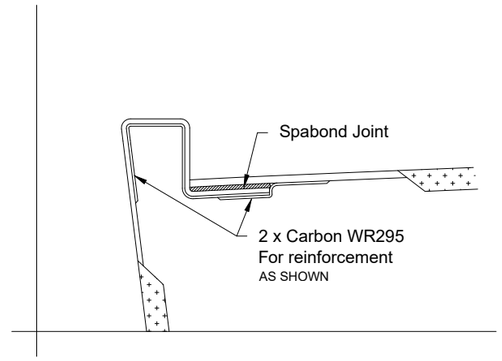

DETAIL B - KEEL FLANGE

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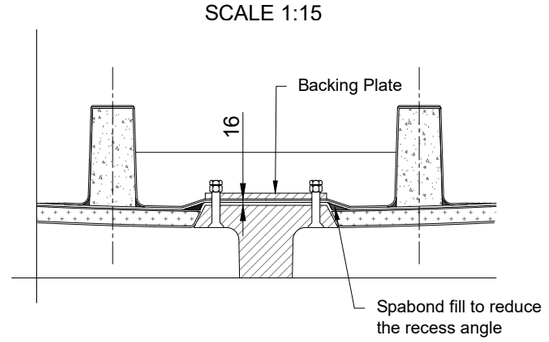

STRUCTURE GRID

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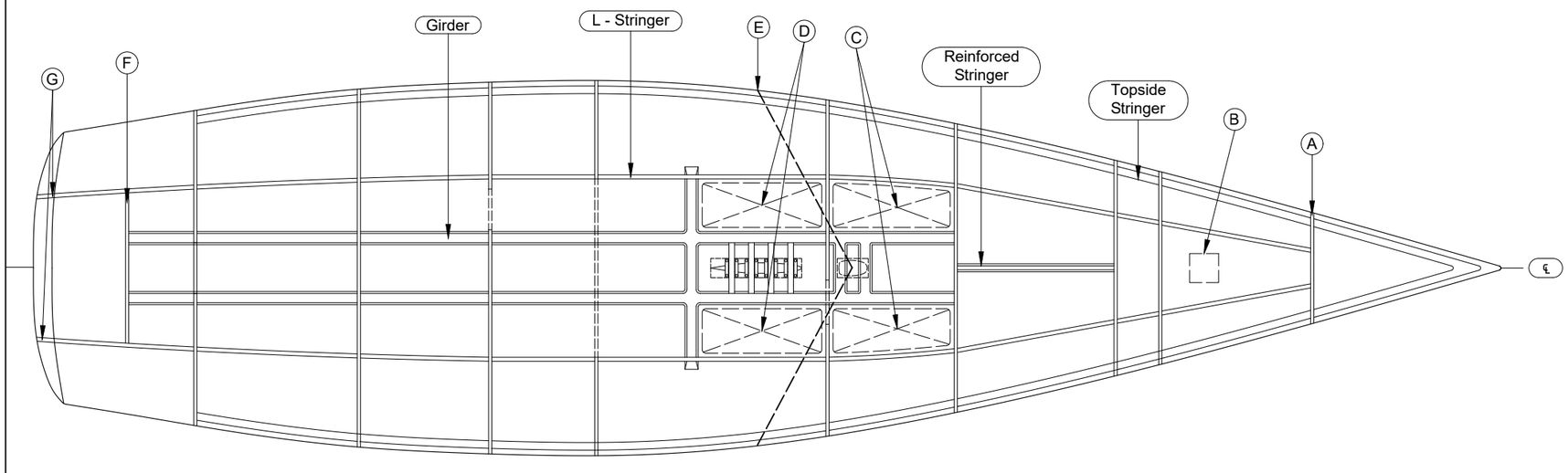

LABEL	ITEM	DESCRIPTION
A	Watertight bulkhead	Watertight bulkhead as on ISO 12215-5.
B	Bow-Thruster	Location of the bow-thruster
C	Fuel Tanks	Fuel tanks located under the cabin sole and between girders.
D	Water Tanks	Water tanks located under the cabin sole and between girders.
E	Shrouds chainplate	Composite shrouds chainplate.
F	Mainsheet attachment	Mainsheet loads transferred to the frame at the showed attachment point.
G	Backstays attachment	Backstay loads transferred to the stringers at the showed attachment points.

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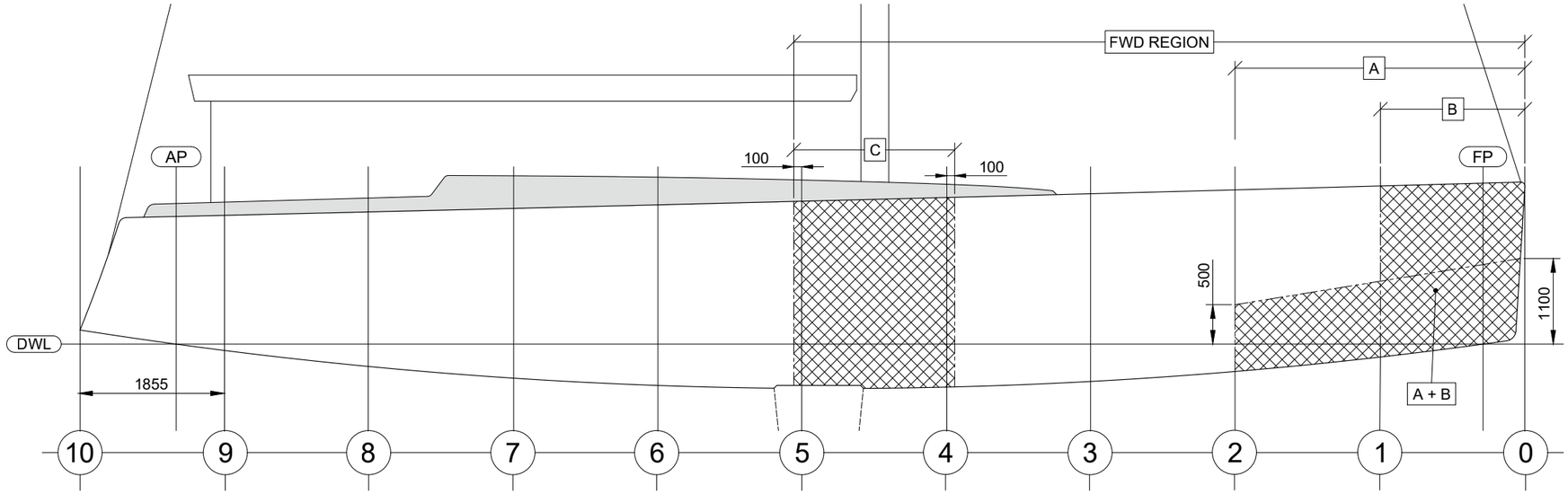

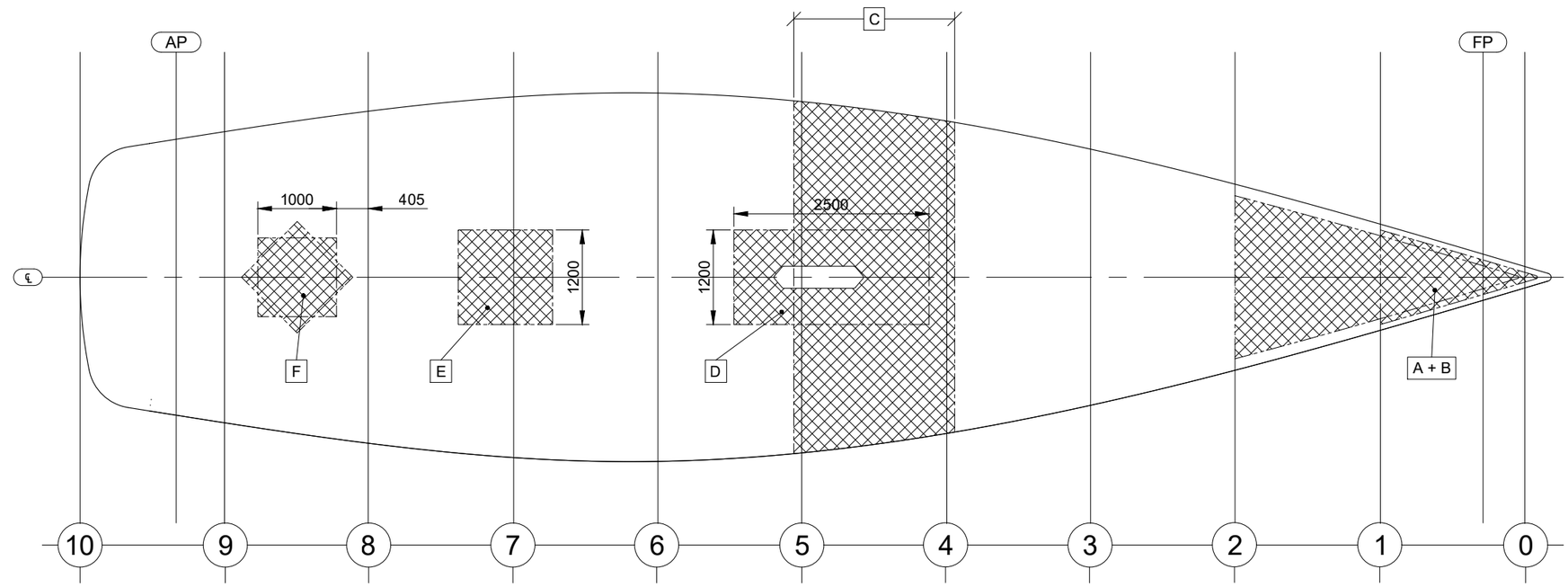

TABLE OF LAMINATES

	N°	MATERIAL	FIBRE WEIGHT	RESIN CONTENT	THICKNESS	ORIENTATION
			g/m2	%	mm	degrees
AFT REGION	0	TOPCOAT	- - -	100		- - -
	1	Carbon - DB 600	600	60	0.74	± 45°
	2	Carbon - WR 295	295	55	0.37	- - -
	3	Carbon - DB 600	600	60	0.74	± 45°
	4	SAN A Core	80000	- - -	40.0	- - -
	7	Carbon - DB 600	600	60	0.74	± 45°
	8	Carbon - WR 295	295	55	0.37	- - -
	9	Carbon - DB 600	600	60	0.74	± 45°
FWD REGION	10	Carbon - DB 600	600	60	0.74	± 45°
	11	Carbon - WR 295	295	55	0.37	- - -
	12	Carbon - DB 600	600	60	0.74	± 45°
	13	SAN A Core	100000	- - -	40.0	- - -
	16	Carbon - DB 600	600	60	0.74	± 45°
	17	Carbon - WR 295	295	55	0.37	- - -
	18	2 x Carbon - DB 600	1200	60	1.48	0/90°
A	20	2 x Carbon - DB 600	1200	60	1.48	± 45°
B	22	2 x Carbon - DB 600	1200	60	1.48	± 45°
C	24	2 x Carbon - UD 250	500	60	0.62	90°
	25	2 x Carbon - DB 600	1200	60	1.48	± 45°
D	27	2 x Carbon - DB 600	1200	60	1.48	± 45°
E	29	2 x Carbon - DB 600	1200	60	1.48	± 45°
F	31	2 x Carbon - DB 600	1200	60	1.48	± 45°

DRAWING ANNOTATIONS

1. Panels above the design waterline are taken as topside panels, as defined in ISO 12215-5.
2. Core in the topside panels is reduced to 30 mm.
3. Reinforcements "A" and "B" should be placed in the outer layer.

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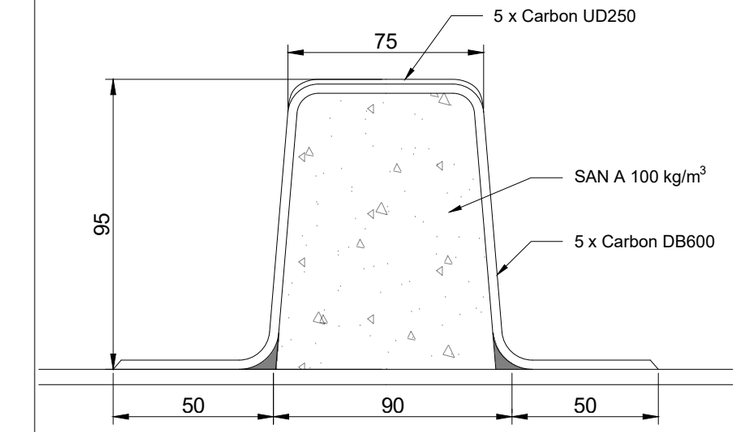
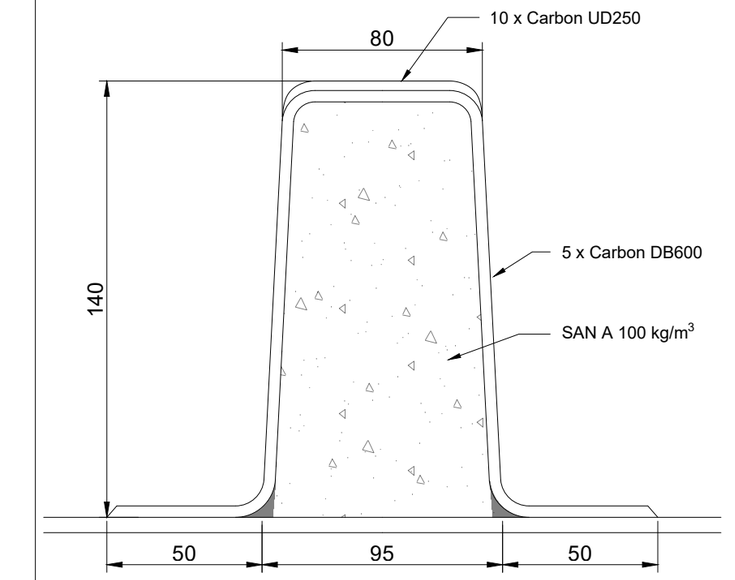
Issue date: 09/01/2019	Scale: 1:70 @ A3	File name: baltic61_SDFP.dwg
Drawn by: Inigo Fuertes	Units: mm	Projection method: n/a
Drawing number: 02		**Drawing title: Baltic 61 Structural Arrangement**
Edition: vol 1	Sheet: 2 of 3	

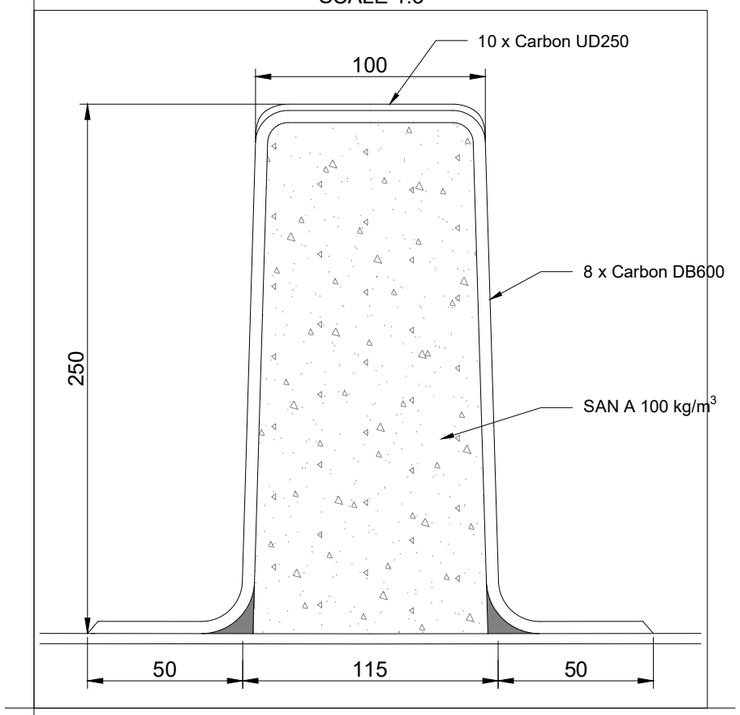
BASIC STRINGER
SCALE 1:2



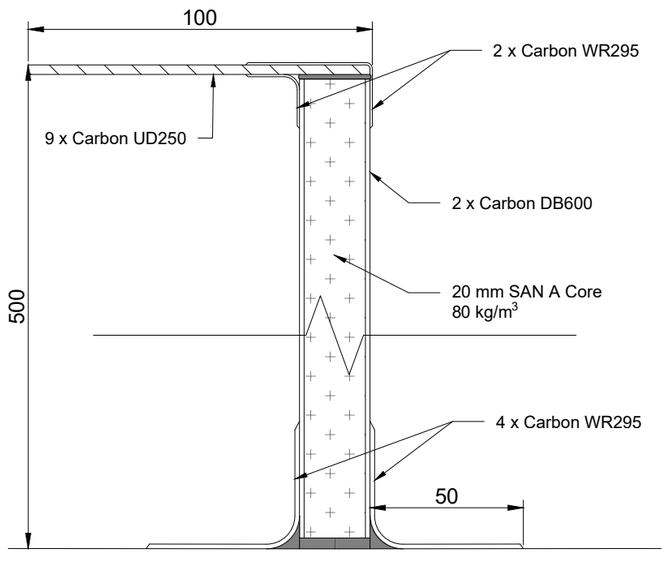
REINFORCED STRINGER
SCALE 1:2



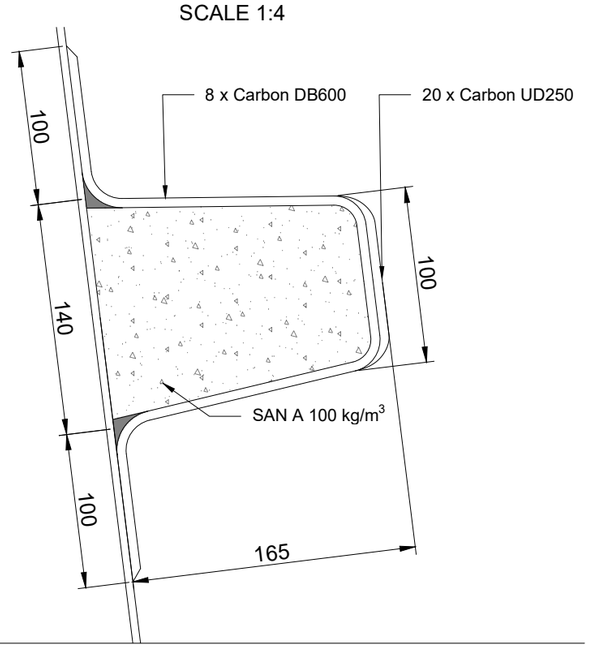
GIRDER
SCALE 1:3



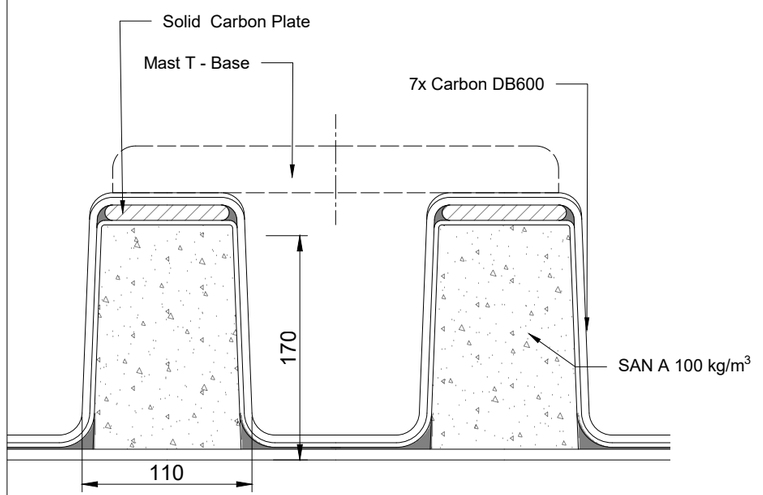
L - STRINGER
SCALE 1:2



TOPSIDE STRINGER
SCALE 1:4



BUTTOCK SECTION @ MAST-STEP
SCALE 1:5



Spabond

Southampton Solent University

Issue date: 09/01/2019	Scale: n.a @ A3	File name: baltic61_SDFP.dwg
Drawn by: Inigo Fuertes	Units: mm	Projection method: n/a
Drawing number: 03		**Drawing title: Baltic 61 Structural Arrangement**
Edition: vol 01	Sheet: 3 of 3	