X-SEA VERIFICATION REPORT 2

Offshore Wind Turbine Jacket Structures

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01	20/12/2019	Offshore wind turbine jacket structure subjected to self-weight, Airy's wave, and Stoke's 5th order wave.	Van Nguyen Dinh	Ki-Du Kim

Summary:

This document reports the verification of X-SEA software using the static analysis of an offshore wind turbine jacket structure subjected to self-weight, Airy's wave, and Stoke's 5^{th} order wave and comparing with the SACS software results. The jacket structure has 138.15 meters height and four fixed pile supports at the bottom of the legs. The reaction at supports, displacement of main legs and internal member forces calculated in X-SEA and SACS are in good agreement.

Table of Contents

Offshore Wind Turbine Jacket Structure

1 Introduction

For the verification of X-SEA software, the static analysis of an offshore wind turbine jacket structure subjected to self-weight, Airy's wave, and Stoke's 5th order wave is carried out using X-SEA and SACS software. The offshore wind jacket structure has 138.15 meters height and four fixed pile supports in the bottom of the legs.

In order to compare the X-SEA results with those of SACS, the reaction at supports, displacement of main legs and internal member forces in both X-SEA and SACS were calculated as shown in the form of tables and plots. The reaction force is taken from the four fixed supports of the bottom of the structure. Displacement and internal forces are compared in each node on all four main legs. All the node positions calculated from the X-SEA and SACS are illustrated in **Figure 1** and **Figure 2**, respectively. The four elements (four meshes) are used for every single member.

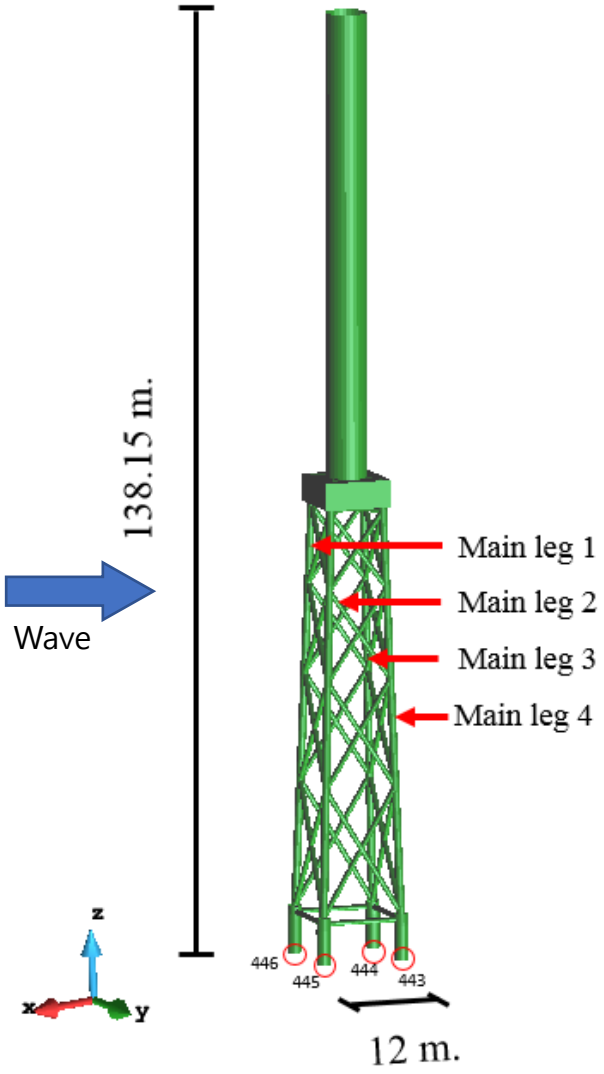

Figure 1. Model of the offshore wind jacket platform in X-SEA.

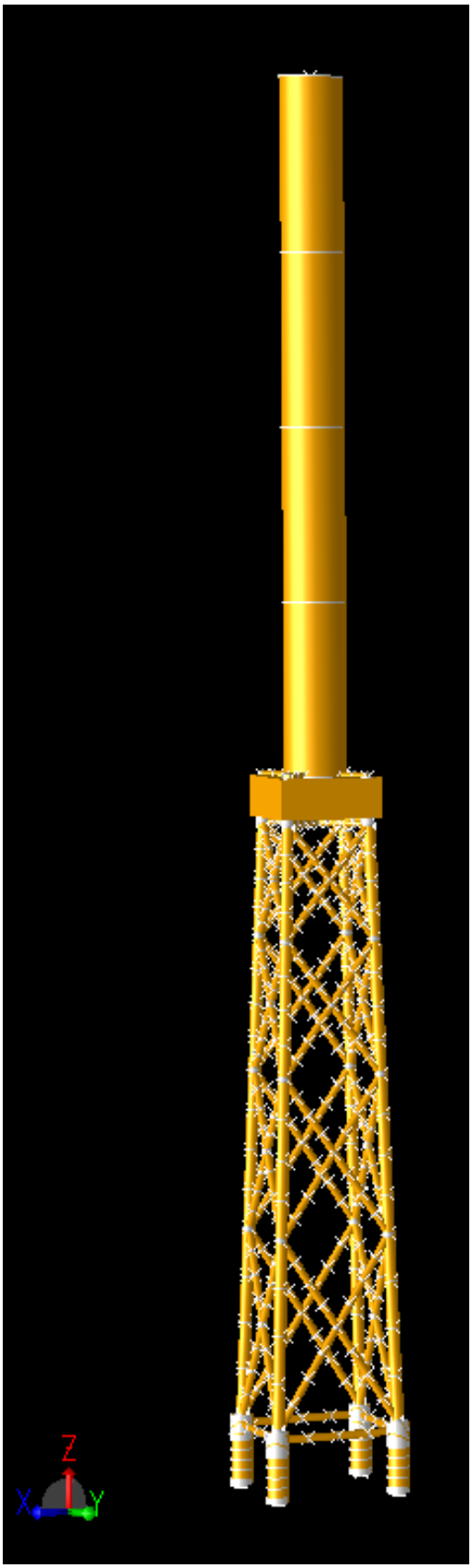

Figure 2. Model of the offshore wind jacket platform in SACS.

2 Geometric and Material Properties of Offshore Wind Jacket Structure

The jacket height is 138.15 m and base dimensions are 12 x 12 m. The tower, legs and bracings of the jacket are in circular hollow sections illustrated in **Figure 3** with their section properties listed in **Table 1**. The piles supporting the jacket structure are in circular solid sections as in **Figure 4** with dimensions listed in **Table 1**. **Table 2** lists section details of the transition piece.

Table 1. Section details of the offshore wind jacket structure legs, bracings and support piles

Section - Circular	Outer Diameter (m.)	Thickness (m.)
Main Leg Type 1	2.081	0.060
Main Leg Type 2	1.200	0.150
Main Leg Type 3	1.200	0.036
Main Leg Type 4	1.200	0.050
Bracing	0.800	0.020
Circular Solid Shape	1.000	0.000
Tower	6.000	0.027

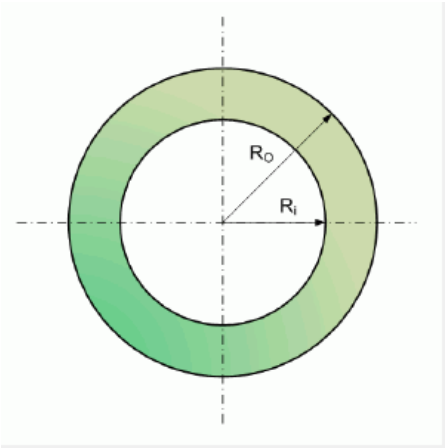

Figure 3. Circular hollow section

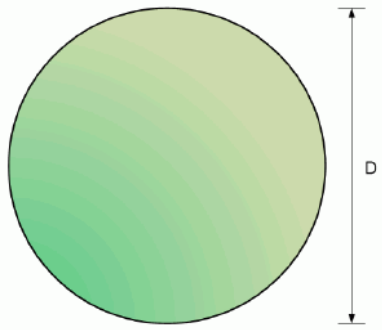

Figure 4. Circular solid section

Table 2. Section detail of the transition piece

Section	Height (B) (m.)	Width (W) (m.)	Depth (m.)
Rectangular	4.000	10.000	10.000

The material properties of steel for the jacket tower, legs and bracings to be used in the analysis are elastic modulus E = 2.0×10^{11} N/m2; Poisson's ratio (ν) = 0.30 and mass density = 7850 kg/m3.

The material properties of concrete for the supporting piles to be used in the analysis are elastic modulus E = 2.5×10^{10} N/m2; Poisson's ratio (ν) = 0.2 and mass density = 2350 kg/m3.

3 Analysis Results of X-SEA and SACS

3.1 Offshore wind jacket structure subjected to self-weight loads

The reactions of the jacket subjected to self-weight loads by X-SEA model and SACS model are in **Table 3** and **Table 4**, respectively. The normalised reactions by X-SEA/SACS results in **Table 5** show good agreement in the results from the two software.

Table 3. Reaction of the jacket subjected to self-weight load by X-SEA model.

	CASE – Self weight ---- Reaction by X-SEA					
Node	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
443	78.538	-78.568	5791.690	528.448	526.919	-0.032
444	78.544	78.565	5791.790	-526.799	528.008	-0.032
445	-78.543	-78.565	5791.690	527.402	-528.004	-0.012
446	-78.539	78.567	5791.790	-527.843	-526.923	-0.018

Table 4. Reaction of the jacket using self-weight loading by SACS model.

	CASE – Self weight ---- Reaction by SACS					
Node	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
1061	-87.990	87.990	5825.740	-582.631	-582.631	0.000
1062	-87.990	-87.990	5825.740	582.631	-582.631	0.000
1063	87.990	87.990	5825.740	-582.631	582.631	0.000
1064	87.990	-87.990	5825.740	582.631	582.631	0.000

Table 5. Normalized reactions of the jacket subjected to self-weight loads by X-SEA/SACS results.

		CASE – Self weight ---- Normalised Solution					
Node		F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
X-SEA	SACS						
443	1061	-	-	0.994	-	-	-
444	1062	-	-	0.994	-	-	-
445	1063	-	-	0.994	-	-	-
446	1064	-	-	0.994	-	-	-

3.2 Offshore wind jacket structure subjected to Airy's wave

Table 6. Environment condition and Airy's wave parameters

Environment condition	Wave parameter
Water depth = 50.00 m. Sea bed level = -50.00 m. Water density = 1025 kg/m^3 Air Density = 1.25 kg/m^3	Wave theory = Airy wave theory Water density = 1025 kg/m^3 Wave height = 12.04 m Wave period = 10 seconds

3.2.1 Wave force

Table 7. Wave force due to Airy's wave

Wave Force						
	X-SEA			SACS		
Elevation (m)	F_X(kN)	F_Y(kN)	F_Z(kN)	F_X(kN)	F_Y(kN)	F_Z(kN)
7.196	10.065	0.110	0.326	10.863	0.062	0.328
4.378	7.778	0.100	0.251	7.979	0.063	0.253
1.053	6.036	0.089	0.194	6.051	0.062	0.195
-2.272	4.707	0.080	0.151	4.717	0.058	0.152
-5.597	3.693	0.071	0.118	3.701	0.055	0.119
-8.922	2.800	0.061	0.090	2.805	0.049	0.090
-12.845	2.150	0.052	0.069	2.152	0.045	0.069
-16.768	1.677	0.044	0.053	1.677	0.038	0.056
-20.691	1.333	0.036	0.042	1.334	0.032	0.046
-24.614	1.048	0.029	0.033	1.047	0.026	0.033
-29.242	0.858	0.021	0.027	0.859	0.020	0.027
-33.870	0.735	0.015	0.024	0.735	0.014	0.023
-43.127	0.665	0.009	0.021	0.666	0.008	0.022

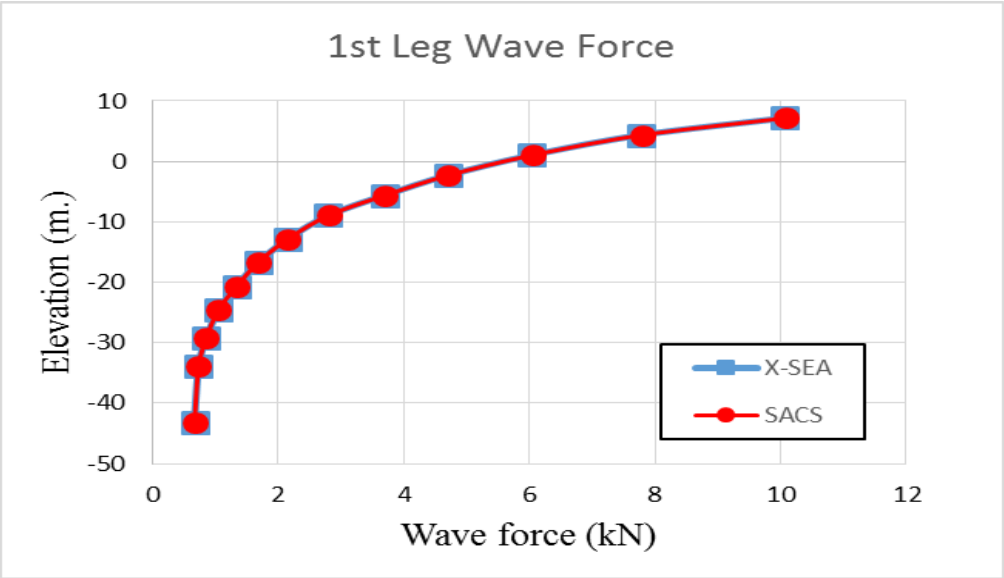

Figure 5. Comparison of wave forces in X-direction according to the height of the 1st leg between X-SEA and SACS results using Airy's wave theory

3.2.2 Reaction

Table 8. Reactions of the offshore wind jacket structure by X-SEA using Airy's wave theory

	Case 1 : Airy ----- Wave Reaction by X-SEA					
Node	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
446	-302.084	24.681	1840.590	-165.064	-1909.670	50.373
445	-301.945	-24.598	1840.930	164.383	-1909.040	-50.406
444	-296.706	-23.186	-1775.640	159.164	-1885.410	37.235
443	-296.604	23.104	-1775.140	-159.189	-1884.480	-37.109

Table 9. Reaction of the offshore wind jacket structure by SACS using Airy's wave theory

	Case 1 : Airy ----- Wave Reaction by SACS					
Node	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
1061	-305.097	27.904	1862.750	-184.695	-1926.776	50.689
1062	-306.084	-27.171	1862.666	179.947	-1933.267	-50.222
1063	-299.909	-26.341	-1809.425	178.575	-1903.492	37.872
1064	-300.979	25.823	-1811.158	-175.173	-1910.232	-37.219

Table 10. Normalised solution (X-SEA/SACS) of jacket reactions by using Airy's wave theory

		Case 1 : Airy ----- Nominal Solution of Reaction					
Node		F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
X-SEA	SACS						
446	1061	0.990	0.884	0.988	0.894	0.991	0.994
445	1062	0.986	0.905	0.988	0.914	0.987	1.004
444	1063	0.989	0.880	0.981	0.891	0.991	0.983
443	1064	0.985	0.895	0.980	0.909	0.987	0.997

3.2.3 Displacement

Table 11. Displacement of the offshore wind jacket structure (1st leg) by X-SEA using Airy's wave

	Case 1 : Airy ----- Displacement from X-SEA (1st Leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.283	-0.028	-0.644	0.000	0.000	0.000
7.1962	10.873	-0.017	-0.658	0.000	0.000	0.000
4.378	10.467	0.000	-0.671	0.000	0.000	0.000
1.053	9.965	0.034	-0.683	0.000	0.000	0.000
-2.272	9.361	0.067	-0.699	0.000	0.000	0.000
-5.597	8.649	0.077	-0.717	0.000	0.000	0.000
-8.922	7.879	0.046	-0.736	0.000	0.000	0.000
-12.845	6.992	-0.065	-0.731	0.000	0.000	0.000
-16.768	6.097	-0.225	-0.724	0.000	0.000	0.000
-20.691	5.185	-0.389	-0.718	0.000	0.000	0.000
-24.614	4.282	-0.514	-0.713	0.000	0.000	0.000
-29.242	3.335	-0.514	-0.573	0.000	0.000	0.000
-33.87	2.482	-0.383	-0.434	0.000	0.000	0.000
-38.499	1.661	-0.210	-0.296	0.000	0.000	0.000
-43.127	0.877	-0.078	-0.155	0.000	0.000	0.000

Table 12. Displacement of the jacket structure (1st leg) by SACS using Airy's wave theory.

	Case 1 : Airy ----- Displacement from SACS (1st Leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.319	-0.041	-0.652	0.000	0.000	0.000
7.1962	10.899	-0.030	-0.665	0.000	0.000	0.000
4.378	10.484	-0.011	-0.679	0.000	0.000	0.000
1.053	9.967	0.024	-0.692	0.000	0.000	0.000
-2.272	9.352	0.057	-0.707	0.000	0.000	0.000
-5.597	8.632	0.069	-0.726	0.000	0.000	0.000
-8.922	7.857	0.037	-0.745	0.000	0.000	0.000
-12.845	6.952	-0.072	-0.740	0.000	0.000	0.000
-16.768	6.041	-0.232	-0.733	0.000	0.000	0.000
-20.691	5.114	-0.397	-0.727	0.000	0.000	0.000
-24.614	4.199	-0.521	-0.722	0.000	0.000	0.000
-29.242	3.232	-0.522	-0.581	0.000	0.000	0.000
-33.87	2.367	-0.389	-0.440	0.000	0.000	0.000
-38.499	1.540	-0.211	-0.300	0.000	0.000	0.000
-43.127	0.752	-0.076	-0.158	0.000	0.000	0.000

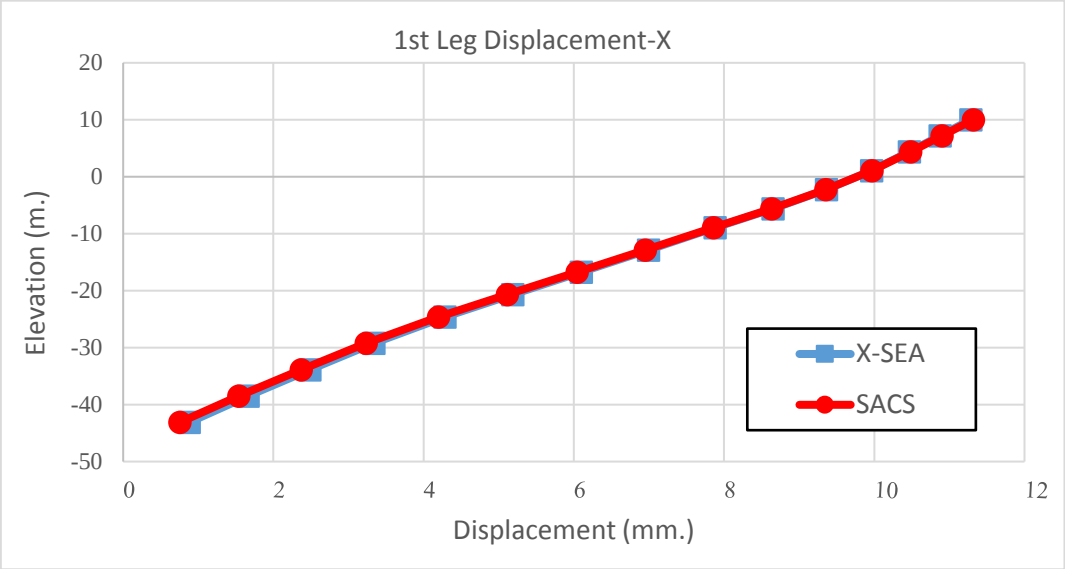

Figure 6. Comparison of X-displacement according to the height of the 1st leg between X-SEA and SACS results using Airy's wave theory.

Table 13. Displacement of the offshore wind jacket (2nd leg) by X-SEA model using Airy's wave theory

	Case 1 : Airy ----- Displacement from X-SEA (2nd Leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.284	0.029	-0.645	0.000	0.000	0.000
7.1962	10.876	0.018	-0.658	0.000	0.000	0.000
4.378	10.470	0.000	-0.672	0.000	0.000	0.000
1.053	9.970	-0.034	-0.684	0.000	0.000	0.000
-2.272	9.365	-0.067	-0.699	0.000	0.000	0.000
-5.597	8.652	-0.078	-0.718	0.000	0.000	0.000
-8.922	7.881	-0.047	-0.737	0.000	0.000	0.000
-12.845	6.993	0.064	-0.731	0.000	0.000	0.000
-16.768	6.097	0.223	-0.725	0.000	0.000	0.000
-20.691	5.184	0.388	-0.719	0.000	0.000	0.000
-24.614	4.280	0.513	-0.714	0.000	0.000	0.000
-29.242	3.333	0.512	-0.573	0.000	0.000	0.000
-33.87	2.481	0.382	-0.434	0.000	0.000	0.000
-38.499	1.661	0.208	-0.296	0.000	0.000	0.000
-43.127	0.877	0.077	-0.155	0.000	0.000	0.000

Table 14. Displacement of offshore wind jacket (2nd leg) by SACS model using Airy's wave theory

	Case 1 : Airy ----- Displacement from SACS (2nd Leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.343	0.020	-0.651	0.000	0.000	0.000
7.1962	10.927	0.010	-0.664	0.000	0.000	0.000
4.378	10.511	-0.008	-0.678	0.000	0.000	0.000
1.053	9.992	-0.041	-0.691	0.000	0.000	0.000
-2.272	9.374	-0.073	-0.706	0.000	0.000	0.000
-5.597	8.651	-0.083	-0.725	0.000	0.000	0.000
-8.922	7.873	-0.051	-0.744	0.000	0.000	0.000
-12.845	6.966	0.060	-0.739	0.000	0.000	0.000
-16.768	6.054	0.221	-0.733	0.000	0.000	0.000
-20.691	5.126	0.388	-0.727	0.000	0.000	0.000
-24.614	4.210	0.512	-0.722	0.000	0.000	0.000
-29.242	3.242	0.515	-0.580	0.000	0.000	0.000
-33.87	2.375	0.384	-0.440	0.000	0.000	0.000
-38.499	1.545	0.207	-0.300	0.000	0.000	0.000
-43.127	0.754	0.074	-0.158	0.000	0.000	0.000

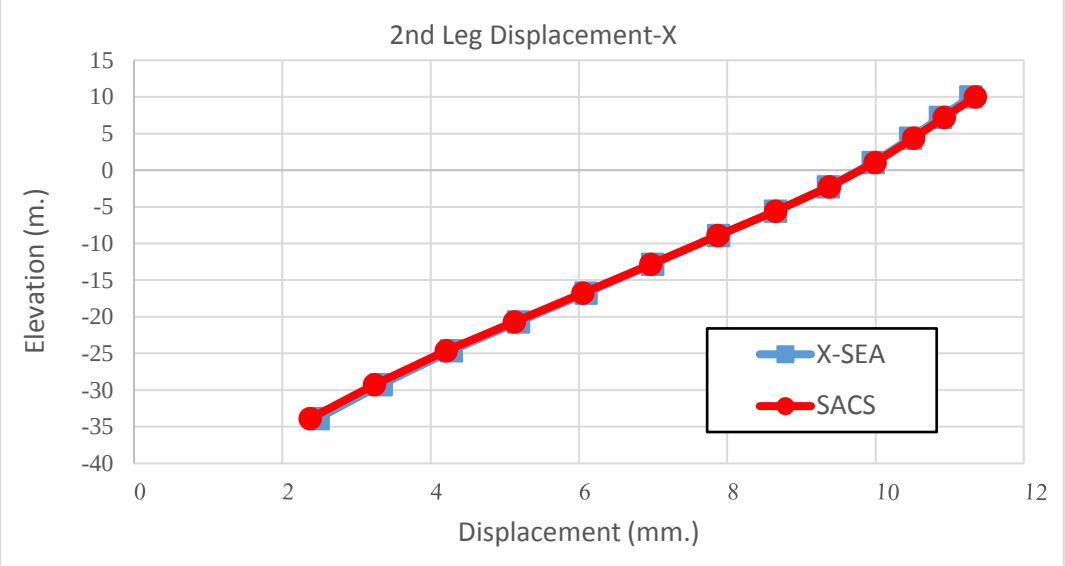

Figure 7. Comparison of X-displacement according to the height of the 2nd leg between X-SEA and SACS results using Airy's wave theory

Table 15. Displacement of the offshore wind jacket (3rd leg) by X-SEA model using Airy's wave theory

	Case 1 : Airy ----- Displacement from X-SEA (3rd leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.283	0.031	0.591	0.000	0.000	0.000
7.1962	10.861	0.027	0.605	0.000	0.000	0.000
4.378	10.439	0.013	0.619	0.000	0.000	0.000
1.053	9.920	-0.018	0.633	0.000	0.000	0.000
-2.272	9.311	-0.050	0.649	0.000	0.000	0.000
-5.597	8.607	-0.064	0.669	0.000	0.000	0.000
-8.922	7.841	-0.042	0.689	0.000	0.000	0.000
-12.845	6.942	0.060	0.687	0.000	0.000	0.000
-16.768	6.036	0.214	0.684	0.000	0.000	0.000
-20.691	5.121	0.372	0.681	0.000	0.000	0.000
-24.614	4.216	0.488	0.679	0.000	0.000	0.000
-29.242	3.250	0.487	0.547	0.000	0.000	0.000
-33.87	2.399	0.366	0.416	0.000	0.000	0.000
-38.499	1.612	0.202	0.284	0.000	0.000	0.000
-43.127	0.865	0.076	0.149	0.000	0.000	0.000

Table 16. Displacement of the offshore wind jacket (3rd leg) by SACS model using Airy's wave theory.

	Case 1 : Airy ----- Displacement from SACS (3rd leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.326	0.035	0.607	0.000	0.000	0.000
7.1962	10.896	0.029	0.621	0.000	0.000	0.000
4.378	10.464	0.014	0.635	0.000	0.000	0.000
1.053	9.926	-0.017	0.649	0.000	0.000	0.000
-2.272	9.302	-0.049	0.666	0.000	0.000	0.000
-5.597	8.585	-0.063	0.685	0.000	0.000	0.000
-8.922	7.812	-0.038	0.706	0.000	0.000	0.000
-12.845	6.897	0.065	0.703	0.000	0.000	0.000
-16.768	5.980	0.221	0.700	0.000	0.000	0.000
-20.691	5.053	0.381	0.696	0.000	0.000	0.000
-24.614	4.138	0.498	0.694	0.000	0.000	0.000
-29.242	3.157	0.498	0.559	0.000	0.000	0.000
-33.87	2.292	0.374	0.425	0.000	0.000	0.000

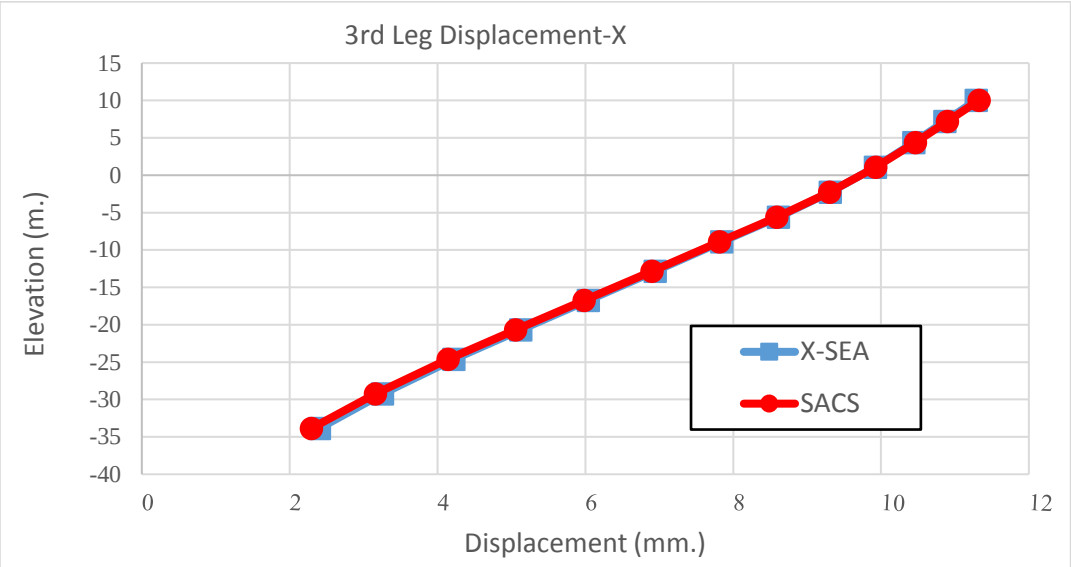

Figure 8. Comparison of X-displacement according to the height of the 3rd leg between X-SEA and SACS results using Airy's wave theory.

Table 17. Displacement of the offshore wind jacket (4th leg) by X-SEA model using Airy's wave theory

	Case 1 : Airy ----- Displacement from X-SEA (4th leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.284	-0.027	0.591	0.000	0.000	0.000
7.1962	10.861	-0.023	0.604	0.000	0.000	0.000
4.378	10.437	-0.010	0.619	0.000	0.000	0.000
1.053	9.917	0.021	0.632	0.000	0.000	0.000
-2.272	9.308	0.052	0.649	0.000	0.000	0.000
-5.597	8.604	0.066	0.669	0.000	0.000	0.000
-8.922	7.839	0.044	0.689	0.000	0.000	0.000
-12.845	6.940	-0.058	0.687	0.000	0.000	0.000
-16.768	6.035	-0.212	0.684	0.000	0.000	0.000
-20.691	5.120	-0.371	0.681	0.000	0.000	0.000
-24.614	4.215	-0.487	0.679	0.000	0.000	0.000
-29.242	3.250	-0.486	0.547	0.000	0.000	0.000
-33.87	2.398	-0.365	0.416	0.000	0.000	0.000
-38.499	1.611	-0.202	0.284	0.000	0.000	0.000
-43.127	0.865	-0.076	0.149	0.000	0.000	0.000

Table 18. SACS displacement of jacket model (4th leg) using Airy's wave theory

	Case 1 : Airy ----- Displacement from SACS (4th leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.344	-0.025	0.606	0.000	0.000	0.000
7.1962	10.914	-0.020	0.620	0.000	0.000	0.000
4.378	10.482	-0.005	0.635	0.000	0.000	0.000
1.053	9.944	0.025	0.649	0.000	0.000	0.000
-2.272	9.321	0.057	0.666	0.000	0.000	0.000
-5.597	8.605	0.070	0.686	0.000	0.000	0.000
-8.922	7.831	0.044	0.706	0.000	0.000	0.000
-12.845	6.916	-0.059	0.704	0.000	0.000	0.000
-16.768	5.996	-0.215	0.700	0.000	0.000	0.000
-20.691	5.067	-0.376	0.696	0.000	0.000	0.000
-24.614	4.150	-0.493	0.694	0.000	0.000	0.000
-29.242	3.166	-0.494	0.560	0.000	0.000	0.000
-33.87	2.299	-0.371	0.426	0.000	0.000	0.000
-38.499	1.500	-0.203	0.291	0.000	0.000	0.000
-43.127	0.743	-0.073	0.153	0.000	0.000	0.000

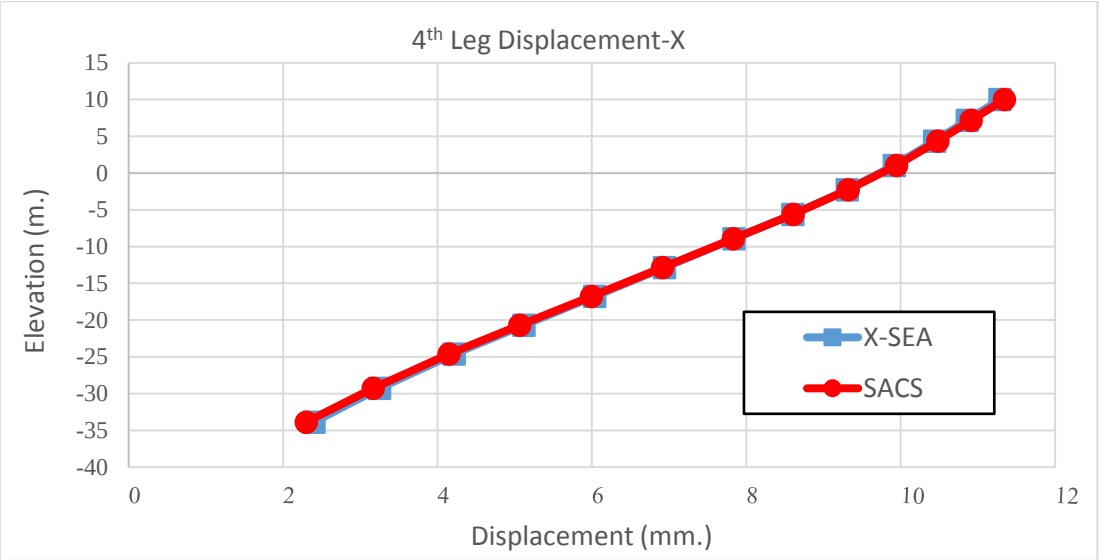

Figure 9. Comparison of X-displacement according to the height of the 4th leg between X-SEA and SACS results using Airy's wave theory.

3.2.4 Member Force

Table 19. Member forces of the offshore wind jacket (1st leg) by X-SEA model using Airy's wave theory

	Case 1: Airy ----- Member force from X-SEA (1st leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-14.522	-0.525	1.955	36.896	-12.285	-4.345
4.378	-14.092	2.714	4.849	36.969	-23.917	0.029
1.053	-156.630	-12.964	-25.156	17.107	99.299	-97.278
-2.272	-156.733	5.071	-6.529	17.080	120.023	-81.046
-5.597	-156.812	19.038	7.953	17.060	92.782	-18.195
-8.922	-156.872	29.907	19.269	17.044	28.056	80.933
-12.845	-769.332	-16.136	-2.375	-2.831	40.003	22.755
-16.768	-769.378	-8.541	5.614	-2.845	17.415	-11.069
-20.691	-769.412	-2.722	11.761	-2.855	-29.168	-22.002
-24.614	-769.436	1.808	16.563	-2.862	-94.501	-15.118
-29.242	-1332.220	-2.115	-9.862	-21.372	-42.100	-9.380
-33.87	-1332.230	1.226	-6.314	-21.378	-13.082	-3.917
-38.499	-1332.240	3.969	-3.419	-21.382	2.602	14.247
-43.127	-1332.250	6.332	-0.949	-21.384	6.902	43.343

Table 20. Member force of the offshore wind jacket (1st leg) by SACS model using Airy's wave theory

	Case 1 : Airy ----- Member force from SACS (1st leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-15.229	0.290	1.963	39.421	-14.280	-4.423
4.378	-15.229	-11.223	13.596	39.421	-28.857	3.709
1.053	-161.720	4.053	-15.331	17.842	93.702	-91.556
-2.272	-161.720	-12.051	1.050	17.842	116.340	-77.116
-5.597	-161.720	-12.051	1.050	17.842	116.340	-77.116
-8.922	-161.720	-24.595	13.863	17.842	90.651	-15.257
-12.845	-780.230	21.405	-6.913	-2.090	30.409	92.040
-16.768	-780.230	12.506	2.266	-2.090	38.715	26.263
-20.691	-780.230	0.535	14.707	-2.090	-32.083	-20.887
-24.614	-780.230	-3.553	18.984	-2.090	-98.556	-14.653
-29.242	-1347.400	4.279	-12.112	-21.468	-91.542	2.916
-33.87	-1347.400	0.470	-8.117	-21.468	-45.051	-7.731
-38.499	-1347.400	-5.134	-2.261	-21.468	1.397	15.402
-43.127	-1347.400	-7.397	0.072	-21.468	6.374	44.513

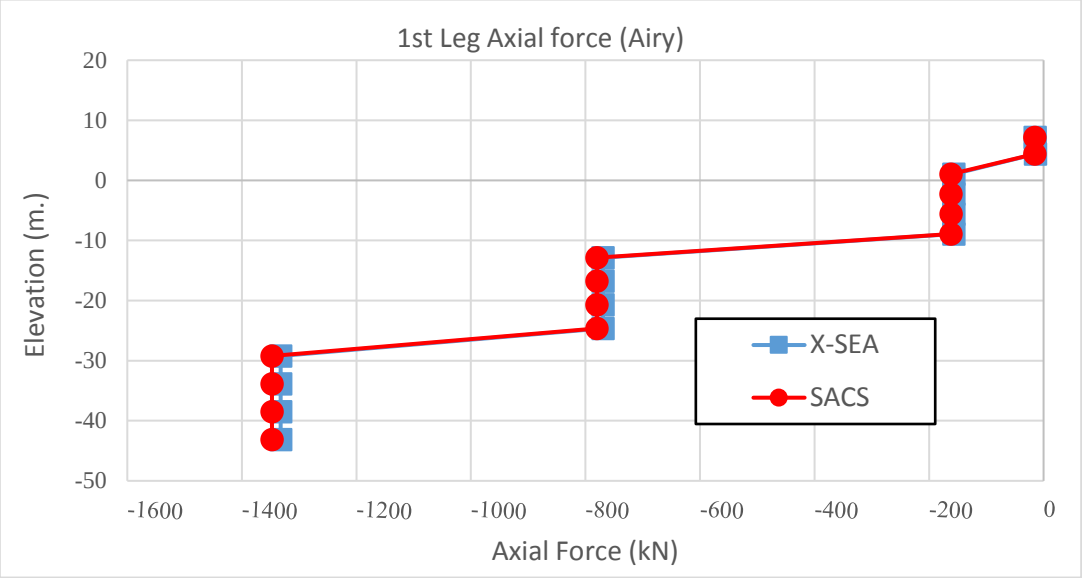

Figure 10. Comparison of axial force according to the height of the 1st leg between X-SEA and SACS results using Airy's wave theory

Table 21. Member force of the offshore wind jacket (2nd leg) modelled by X-SEA using Airy's wave theory

	Case 1 : Airy ----- Member force from X-SEA (2nd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-14.667	-0.571	-1.904	-36.642	12.195	-4.297
4.378	-14.250	1.853	-4.798	-36.199	23.421	-0.051
1.053	-159.081	-14.183	25.065	-16.356	-100.546	-98.072
-2.272	-159.182	4.149	6.437	-16.501	-120.882	-81.535
-5.597	-159.259	18.343	-8.045	-16.612	-93.273	-18.379
-8.922	-159.318	29.385	-19.361	-16.696	-28.194	81.055
-12.845	-770.713	-16.699	2.346	3.121	-40.129	22.940
-16.768	-770.757	-8.970	-5.643	3.044	-17.385	-10.906
-20.691	-770.789	-3.055	-11.790	2.989	29.342	-21.861
-24.614	-770.813	1.545	-16.592	2.948	94.811	-14.999
-29.242	-1332.840	-2.360	9.880	21.552	42.052	-9.259
-33.87	-1332.860	1.027	6.332	21.519	12.971	-3.824
-38.499	-1332.860	3.801	3.437	21.497	-2.783	14.312
-43.127	-1332.870	6.183	0.967	21.484	-7.157	43.380

Table 22. Member forces of the offshore wind jacket (2nd leg) modelled by SACS using Airy's wave theory

	Case 1 : Airy ----- Member force from SACS (2nd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-14.354	0.985	-1.390	-40.913	10.799	-7.611
4.378	-14.354	-10.528	-13.023	-40.913	23.760	-1.440
1.053	-159.750	3.885	15.176	-17.512	-94.246	-92.254
-2.272	-159.750	-12.219	-1.206	-17.512	-116.370	-77.257
-5.597	-159.750	-12.219	-1.206	-17.512	-116.370	-77.257
-8.922	-159.750	-24.763	-14.019	-17.512	-90.158	-14.839
-12.845	-778.220	21.473	6.971	1.891	-29.660	92.832
-16.768	-778.220	12.573	-2.208	1.891	-38.194	26.790
-20.691	-778.220	0.602	-14.649	1.891	32.147	-20.891
-24.614	-778.220	-3.486	-18.926	1.891	98.393	-14.923
-29.242	-1347.000	4.264	12.103	21.165	91.370	2.713
-33.87	-1347.000	-5.150	2.252	21.165	-1.445	15.414
-38.499	-1347.000	-5.150	2.252	21.165	-1.445	15.414
-43.127	-1347.000	-7.413	-0.081	21.165	-6.380	44.597

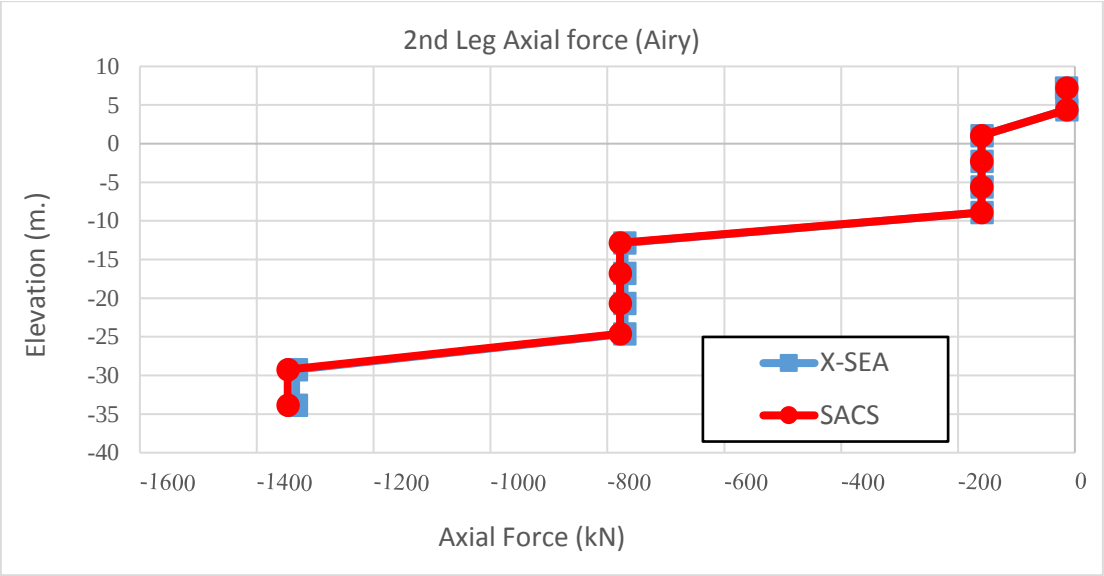

Figure 11. Comparison of axial forces according to the height of the 2nd leg between X-SEA and SACS results using Airy's wave theory

Table 23. Member forces of the offshore wind jacket (3rd leg) modelled by X-SEA using Airy's wave theory

	Case 1 : Airy ----- Member force from X-SEA (3rd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	9.325	1.538	1.977	29.451	-11.465	12.786
4.378	8.961	-1.346	4.391	29.521	-22.144	11.910
1.053	123.934	12.109	-21.421	11.821	84.302	85.661
-2.272	124.029	-3.449	-6.541	11.799	105.156	74.628
-5.597	124.100	-15.160	4.582	11.784	89.214	24.504
-8.922	124.154	-23.971	12.887	11.772	45.800	-55.035
-12.845	700.871	13.868	2.017	-1.816	39.682	-27.001
-16.768	700.910	8.273	7.190	-1.827	10.993	5.586
-20.691	700.938	4.270	10.842	-1.835	-31.906	22.428
-24.614	700.958	1.401	13.422	-1.841	-84.841	27.984
-29.242	1271.240	0.379	-6.832	-15.856	-45.201	2.316
-33.87	1271.260	-1.282	-5.381	-15.861	-20.437	-3.616
-38.499	1271.260	-2.431	-4.390	-15.864	-0.203	-14.868
-43.127	1271.270	-3.237	-3.690	-15.866	16.827	-29.851

Table 24. Member forces of the offshore wind jacket (3rd leg) modelled by SACS using Airy's wave theory

	Case 1 : Airy ----- Member force from SACS (3rd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	11.514	-1.869	1.630	32.726	-8.328	15.882
4.378	11.514	8.147	11.297	32.726	-20.456	13.356
1.053	132.410	-3.566	-13.257	10.982	80.212	80.832
-2.272	132.410	9.867	0.423	10.982	101.960	69.303
-5.597	132.410	9.867	0.423	10.982	101.960	69.303
-8.922	132.410	20.019	9.209	10.982	86.562	18.767
-12.845	720.610	-17.752	-1.177	-1.982	46.090	-86.043
-16.768	720.610	-11.119	5.002	-1.982	37.883	-30.076
-20.691	720.610	-2.989	12.439	-1.982	-33.976	21.793
-24.614	720.610	-0.556	14.612	-1.982	-87.336	28.494
-29.242	1296.400	-1.391	-7.899	-16.313	-79.246	0.791
-33.87	1296.400	0.627	-6.124	-16.313	-47.031	2.264
-38.499	1296.400	2.010	-4.926	-16.313	-21.607	-4.040
-43.127	1296.400	3.662	-3.490	-16.313	16.689	-31.159

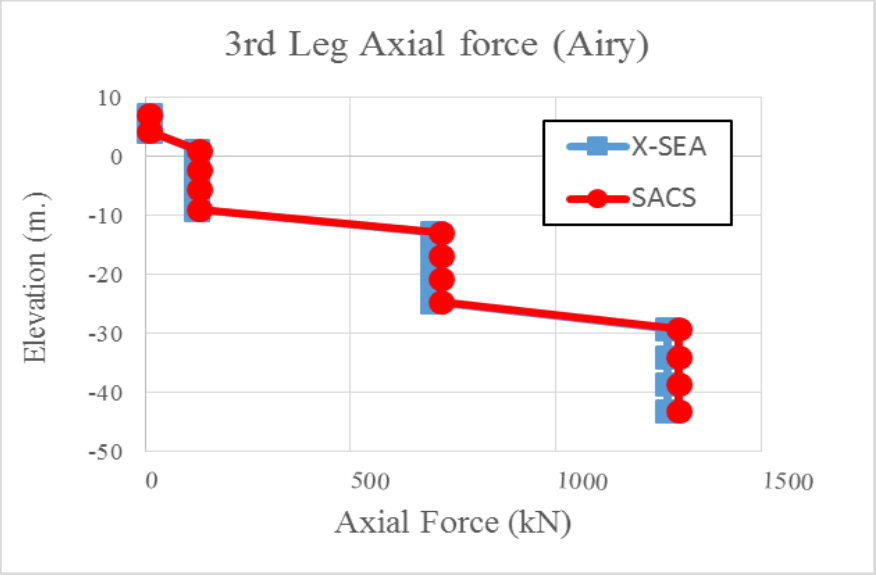

Figure 12. Comparison of axial forces according to the height of the 3rd leg between X-SEA and SACS results using Airy's wave theory

Table 25. Member forces of the jacket (4th leg) modelled by X-SEA using Airy's wave theory

	Case 1 : Airy ----- Member force from X-SEA (4th leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	8.650	1.533	-1.930	-29.761	10.907	13.132
4.378	8.262	-0.626	-4.344	-29.385	21.234	12.242
1.053	121.070	13.342	21.536	-11.372	-83.491	84.873
-2.272	121.169	-2.499	6.656	-11.500	-104.652	74.133
-5.597	121.244	-14.423	-4.467	-11.597	-89.034	24.301
-8.922	121.301	-23.395	-12.773	-11.670	-45.959	-54.945
-12.845	700.110	14.262	-2.027	2.053	-39.981	-26.822
-16.768	700.152	8.547	-7.201	1.990	-11.213	5.656
-20.691	700.182	4.459	-10.853	1.945	31.755	22.389
-24.614	700.204	1.529	-13.433	1.913	84.750	27.836
-29.242	1271.250	0.495	6.831	15.924	45.159	2.366
-33.87	1271.270	-1.207	5.381	15.900	20.412	-3.627
-38.499	1271.270	-2.383	4.390	15.885	0.190	-14.938
-43.127	1271.280	-3.206	3.689	15.875	-16.831	-29.980

Table 26. Member forces of the jacket (4th leg) modelled by SACS using Airy's wave theory

	Case 1 : Airy ----- Member force from SACS (4th leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	8.741	-1.809	-1.777	-33.284	8.749	15.583
4.378	8.741	8.206	-11.445	-33.284	21.293	12.889
1.053	128.970	-3.682	13.377	-11.563	-79.883	80.648
-2.272	128.970	9.750	0.543	-11.563	-102.030	69.505
-5.597	128.970	9.750	0.543	-11.563	-102.030	69.505
-8.922	128.970	19.903	-9.089	-11.563	-87.032	19.357
-12.845	720.320	-17.676	1.092	1.303	-47.062	-85.152
-16.768	720.320	-11.043	-5.088	1.303	-38.519	-29.484
-20.691	720.320	-2.913	-12.524	1.303	34.011	21.789
-24.614	720.320	-0.480	-14.698	1.303	87.708	28.191
-29.242	1297.200	-1.406	7.917	15.825	79.382	0.599
-33.87	1297.200	0.612	6.142	15.825	47.086	2.142
-38.499	1297.200	1.995	4.943	15.825	21.581	-4.093
-43.127	1297.200	3.647	3.508	15.825	-16.877	-31.072

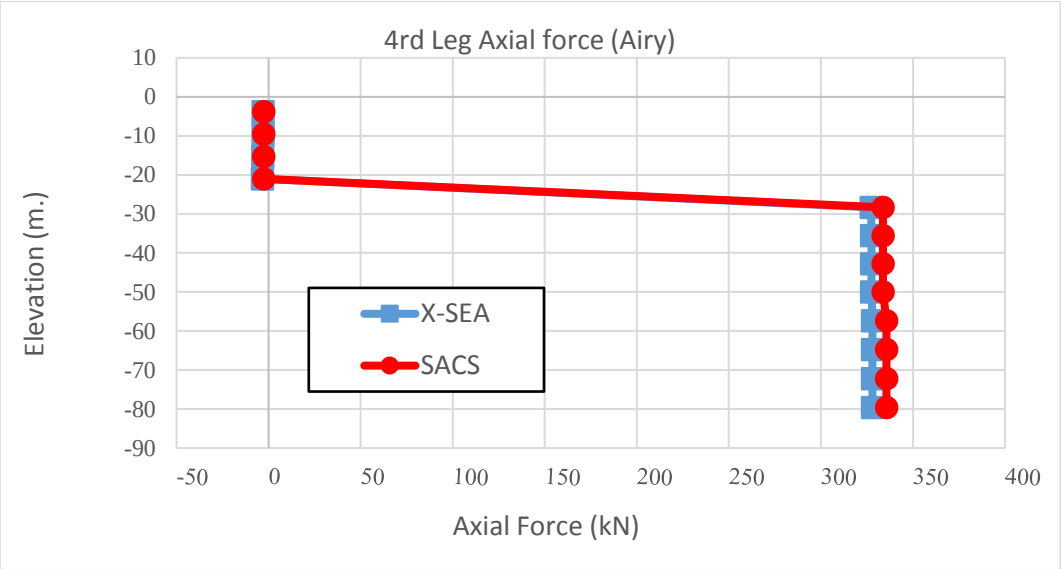

Figure 13. Comparison of axial forces according to the height of the 4th leg between X-SEA and SACS results using Airy's wave theory.

3.3 Offshore wind jacket structure subjected to Stoke's wave

Table 27. Environment condition and wave parameters

Environment condition	Wave parameter
Water depth = 50 m.	Wave theory = Stoke wave theory
Sea bed level = -50 m.	Water density = 1025 kg/m^3
Water density = 1025 kg/m^3	Wave height = 12.04 m
Air Density = 1.25 kg/m^3	Wave period = 10 seconds

3.3.1 *Wave forces*

Table 28. Wave forces due to Stoke's wave

Wave Force						
	X-SEA			SACS		
Elevation (m)	F_X(kN)	F_Y(kN)	F_Z(kN)	F_X(kN)	F_Y(kN)	F_Z(kN)
4.378	9.609	0.115	0.311	9.623	0.071	0.313
1.053	7.453	0.103	0.240	7.471	0.069	0.242
-2.272	5.812	0.092	0.187	5.828	0.066	0.188
-5.597	4.560	0.082	0.146	4.571	0.062	0.147
-8.922	3.603	0.072	0.115	3.610	0.057	0.116
-12.845	2.757	0.062	0.088	2.758	0.051	0.089
-16.768	2.139	0.052	0.068	2.136	0.045	0.068
-20.691	1.686	0.044	0.054	1.681	0.039	0.054
-24.614	1.355	0.037	0.043	1.348	0.033	0.043
-29.242	1.079	0.029	0.034	1.070	0.026	0.034
-33.870	0.893	0.022	0.029	0.882	0.020	0.028
-43.127	0.773	0.015	0.025	0.763	0.014	0.025

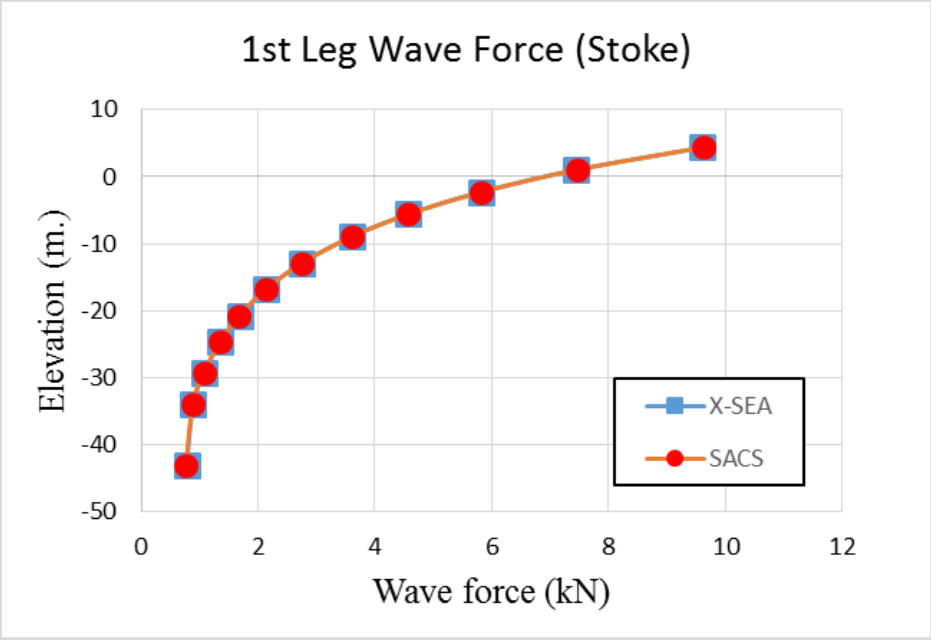

Figure 14. Comparison of wave force in X-direction according to the height of the 1st leg between X-SEA and SACS results using Stoke's wave theory

3.3.2 Reaction

Table 29. Reactions of the offshore wind jacket structure modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Wave Reaction by X-SEA (1st leg)					
Node	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
446	-312.275	25.763	1922.120	-172.681	-1973.200	52.000
445	-312.128	-25.679	1922.470	171.984	-1972.560	-52.037
444	-306.788	-24.191	-1853.780	166.431	-1948.430	38.681
443	-306.691	24.107	-1853.260	-166.470	-1947.480	-38.545

Table 30. Reactions of the offshore wind jacket structure modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Wave Reaction by SACS (1st leg)					
Node	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
1061	-316.628	29.178	1952.389	-193.532	-1998.954	52.204
1062	-317.444	-28.502	1951.904	189.167	-2004.321	-51.827
1063	-311.572	-27.515	-1895.488	186.913	-1976.180	39.843
1064	-312.471	27.108	-1897.277	-184.228	-1981.844	-39.283

Table 31. Normalised solution (X-SEA/SACS) of reaction of jacket structure using Stoke's wave theory

		Case 2 : Stoke ------- Normalised Solution of Reaction					
Node		F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
X-SEA	SACS						
446	1061	0.986	0.883	0.984	0.892	0.987	0.996
445	1062	0.983	0.901	0.985	0.909	0.984	1.004
444	1063	0.985	0.879	0.978	0.890	0.986	0.971
443	1064	0.982	0.889	0.977	0.904	0.983	0.981

3.3.3 Displacement

Table 32. Displacement of the offshore wind jacket (1st leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from X-SEA (1st Leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.823	-0.028	-0.680	0.000	0.000	0.000
7.1962	11.386	-0.017	-0.694	0.000	0.000	0.000
4.378	10.941	0.001	-0.709	0.000	0.000	0.000
1.053	10.391	0.036	-0.722	0.000	0.000	0.000
-2.272	9.742	0.069	-0.738	0.000	0.000	0.000
-5.597	8.992	0.079	-0.757	0.000	0.000	0.000
-8.922	8.188	0.046	-0.776	0.000	0.000	0.000
-12.845	7.260	-0.070	-0.770	0.000	0.000	0.000
-16.768	6.325	-0.237	-0.762	0.000	0.000	0.000
-20.691	5.374	-0.410	-0.755	0.000	0.000	0.000
-24.614	4.435	-0.540	-0.749	0.000	0.000	0.000
-29.242	3.452	-0.539	-0.601	0.000	0.000	0.000
-33.87	2.568	-0.402	-0.456	0.000	0.000	0.000
-38.499	1.717	-0.220	-0.310	0.000	0.000	0.000
-43.127	0.906	-0.082	-0.162	0.000	0.000	0.000

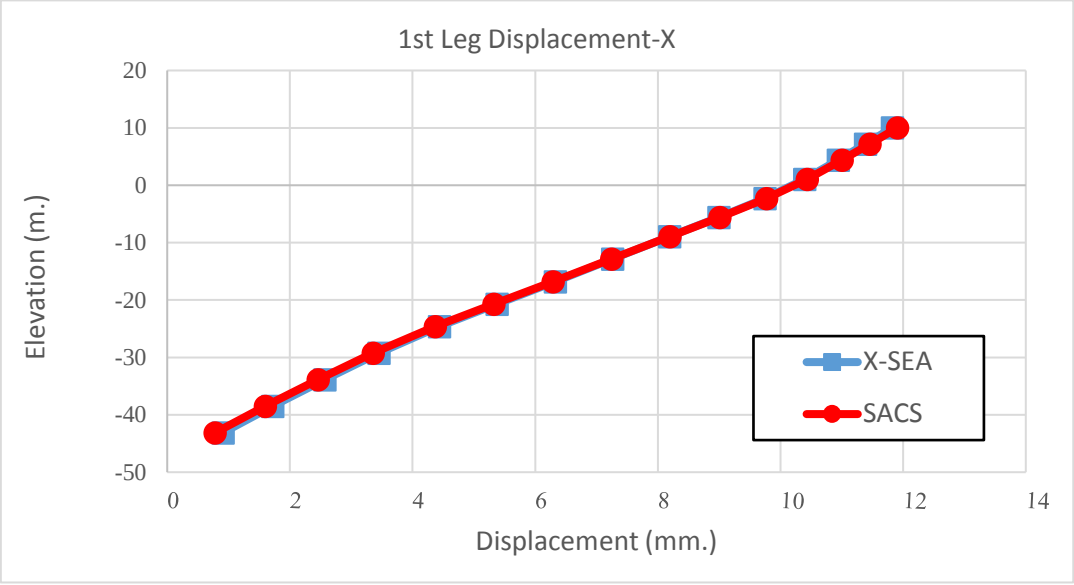

Figure 15. Comparison of X-displacement according to the height of the 1st leg between X-SEA and SACS results using Stoke's wave theory

Table 33. Displacement of the offshore wind jacket (1st leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from SACS (1st Leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.906	-0.042	-0.689	0.000	0.000	0.000
7.1962	11.457	-0.030	-0.704	0.000	0.000	0.000
4.378	11.001	-0.010	-0.719	0.000	0.000	0.000
1.053	10.433	0.025	-0.733	0.000	0.000	0.000
-2.272	9.771	0.060	-0.749	0.000	0.000	0.000
-5.597	9.009	0.071	-0.768	0.000	0.000	0.000
-8.922	8.195	0.038	-0.787	0.000	0.000	0.000
-12.845	7.245	-0.077	-0.781	0.000	0.000	0.000
-16.768	6.290	-0.245	-0.774	0.000	0.000	0.000
-20.691	5.321	-0.419	-0.767	0.000	0.000	0.000
-24.614	4.366	-0.548	-0.761	0.000	0.000	0.000
-29.242	3.358	-0.549	-0.612	0.000	0.000	0.000
-33.87	2.458	-0.409	-0.464	0.000	0.000	0.000
-38.499	1.597	-0.222	-0.316	0.000	0.000	0.000
-43.127	0.780	-0.079	-0.165	0.000	0.000	0.000

Table 34. Displacement of the offshore wind jacket (2nd leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from X-SEA (2nd)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.825	0.029	-0.681	0.000	0.000	0.000
7.1962	11.389	0.018	-0.695	0.000	0.000	0.000
4.378	10.945	0.000	-0.709	0.000	0.000	0.000
1.053	10.396	-0.035	-0.722	0.000	0.000	0.000
-2.272	9.747	-0.069	-0.738	0.000	0.000	0.000
-5.597	8.995	-0.080	-0.757	0.000	0.000	0.000
-8.922	8.189	-0.047	-0.776	0.000	0.000	0.000
-12.845	7.260	0.069	-0.770	0.000	0.000	0.000
-16.768	6.324	0.236	-0.763	0.000	0.000	0.000
-20.691	5.373	0.408	-0.755	0.000	0.000	0.000
-24.614	4.434	0.538	-0.749	0.000	0.000	0.000
-29.242	3.451	0.537	-0.602	0.000	0.000	0.000
-33.87	2.567	0.400	-0.456	0.000	0.000	0.000
-38.499	1.717	0.218	-0.310	0.000	0.000	0.000
-43.127	0.906	0.081	-0.162	0.000	0.000	0.000

Table 35. Displacement of the offshore wind jacket (2nd leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from SACS (2nd leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.927	0.022	-0.688	0.000	0.000	0.000
7.1962	11.480	0.010	-0.703	0.000	0.000	0.000
4.378	11.024	-0.008	-0.718	0.000	0.000	0.000
1.053	10.454	-0.042	-0.732	0.000	0.000	0.000
-2.272	9.789	-0.075	-0.748	0.000	0.000	0.000
-5.597	9.025	-0.086	-0.767	0.000	0.000	0.000
-8.922	8.208	-0.051	-0.787	0.000	0.000	0.000
-12.845	7.257	0.065	-0.781	0.000	0.000	0.000
-16.768	6.301	0.235	-0.773	0.000	0.000	0.000
-20.691	5.331	0.410	-0.766	0.000	0.000	0.000
-24.614	4.375	0.540	-0.760	0.000	0.000	0.000
-29.242	3.366	0.543	-0.611	0.000	0.000	0.000
-33.87	2.464	0.404	-0.463	0.000	0.000	0.000
-38.499	1.601	0.218	-0.316	0.000	0.000	0.000
-43.127	0.782	0.078	-0.165	0.000	0.000	0.000

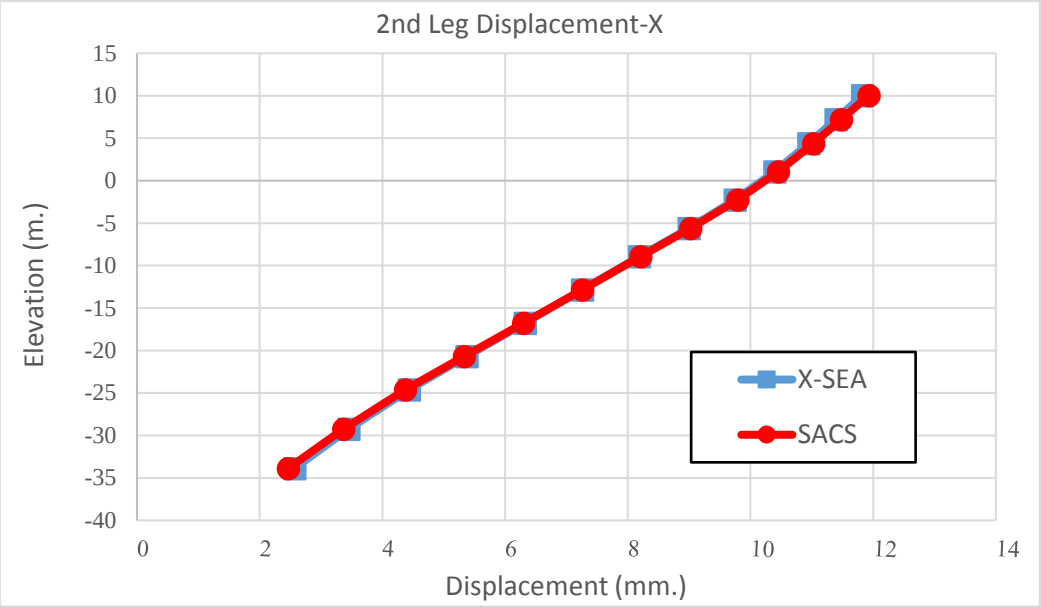

Figure 16. Comparison of X-displacement according to the height of the 2nd leg between X-SEA and SACS results using Stoke's wave theory

Table 36. Displacement of the offshore wind jacket (3rd leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from X-SEA (3rd leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.821	0.034	0.624	0.000	0.000	0.000
7.1962	11.371	0.031	0.638	0.000	0.000	0.000
4.378	10.910	0.016	0.653	0.000	0.000	0.000
1.053	10.342	-0.017	0.668	0.000	0.000	0.000
-2.272	9.690	-0.051	0.686	0.000	0.000	0.000
-5.597	8.948	-0.067	0.706	0.000	0.000	0.000
-8.922	8.149	-0.043	0.726	0.000	0.000	0.000
-12.845	7.210	0.063	0.724	0.000	0.000	0.000
-16.768	6.264	0.225	0.720	0.000	0.000	0.000
-20.691	5.310	0.391	0.715	0.000	0.000	0.000
-24.614	4.368	0.513	0.713	0.000	0.000	0.000
-29.242	3.366	0.512	0.574	0.000	0.000	0.000
-33.87	2.483	0.384	0.436	0.000	0.000	0.000
-38.499	1.667	0.212	0.297	0.000	0.000	0.000
-43.127	0.894	0.080	0.156	0.000	0.000	0.000

Table 37. Displacement of the offshore wind jacket (3rd leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from SACS (3rd leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.910	0.036	0.642	0.000	0.000	0.000
7.1962	11.450	0.031	0.657	0.000	0.000	0.000
4.378	10.977	0.015	0.673	0.000	0.000	0.000
1.053	10.388	-0.019	0.688	0.000	0.000	0.000
-2.272	9.719	-0.052	0.706	0.000	0.000	0.000
-5.597	8.962	-0.066	0.726	0.000	0.000	0.000
-8.922	8.151	-0.040	0.746	0.000	0.000	0.000
-12.845	7.193	0.068	0.743	0.000	0.000	0.000
-16.768	6.231	0.233	0.739	0.000	0.000	0.000
-20.691	5.262	0.401	0.734	0.000	0.000	0.000
-24.614	4.307	0.524	0.731	0.000	0.000	0.000
-29.242	3.285	0.525	0.589	0.000	0.000	0.000
-33.87	2.385	0.393	0.447	0.000	0.000	0.000
-38.499	1.554	0.215	0.305	0.000	0.000	0.000
-43.127	0.769	0.078	0.160	0.000	0.000	0.000

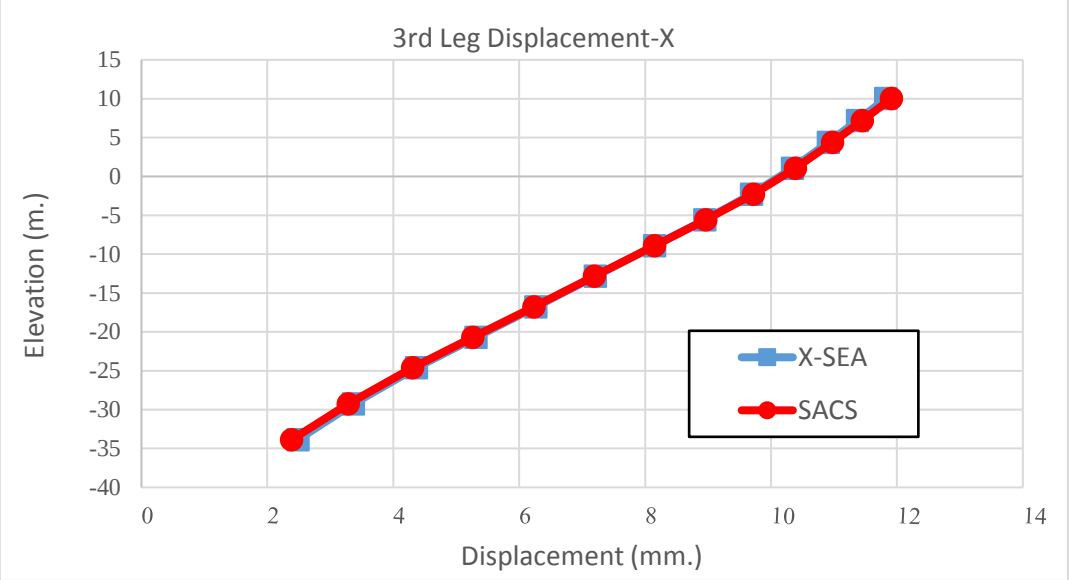

Figure 17. Comparison of X-displacement according to the height of the 3rd leg between X-SEA and SACS results using Stoke's wave theory

Table 38. Displacement of the offshore wind jacket (4th leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from X-SEA (4th leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.823	-0.030	0.623	0.000	0.000	0.000
7.1962	11.371	-0.027	0.638	0.000	0.000	0.000
4.378	10.908	-0.013	0.653	0.000	0.000	0.000
1.053	10.339	0.020	0.668	0.000	0.000	0.000
-2.272	9.687	0.053	0.686	0.000	0.000	0.000
-5.597	8.946	0.069	0.706	0.000	0.000	0.000
-8.922	8.148	0.045	0.726	0.000	0.000	0.000
-12.845	7.209	-0.061	0.724	0.000	0.000	0.000
-16.768	6.263	-0.223	0.720	0.000	0.000	0.000
-20.691	5.309	-0.390	0.715	0.000	0.000	0.000
-24.614	4.368	-0.512	0.713	0.000	0.000	0.000
-29.242	3.366	-0.511	0.574	0.000	0.000	0.000
-33.87	2.483	-0.383	0.436	0.000	0.000	0.000

Table 39. Displacement of the offshore wind jacket (4th leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from SACS (4th leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
10.014	11.925	-0.030	0.642	0.000	0.000	0.000
7.1962	11.465	-0.025	0.657	0.000	0.000	0.000
4.378	10.992	-0.009	0.673	0.000	0.000	0.000
1.053	10.403	0.024	0.688	0.000	0.000	0.000
-2.272	9.734	0.057	0.706	0.000	0.000	0.000
-5.597	8.978	0.071	0.726	0.000	0.000	0.000
-8.922	8.168	0.044	0.746	0.000	0.000	0.000
-12.845	7.209	-0.064	0.744	0.000	0.000	0.000
-16.768	6.245	-0.229	0.739	0.000	0.000	0.000
-20.691	5.274	-0.398	0.734	0.000	0.000	0.000
-24.614	4.316	-0.521	0.731	0.000	0.000	0.000
-29.242	3.292	-0.522	0.589	0.000	0.000	0.000
-33.87	2.391	-0.391	0.448	0.000	0.000	0.000

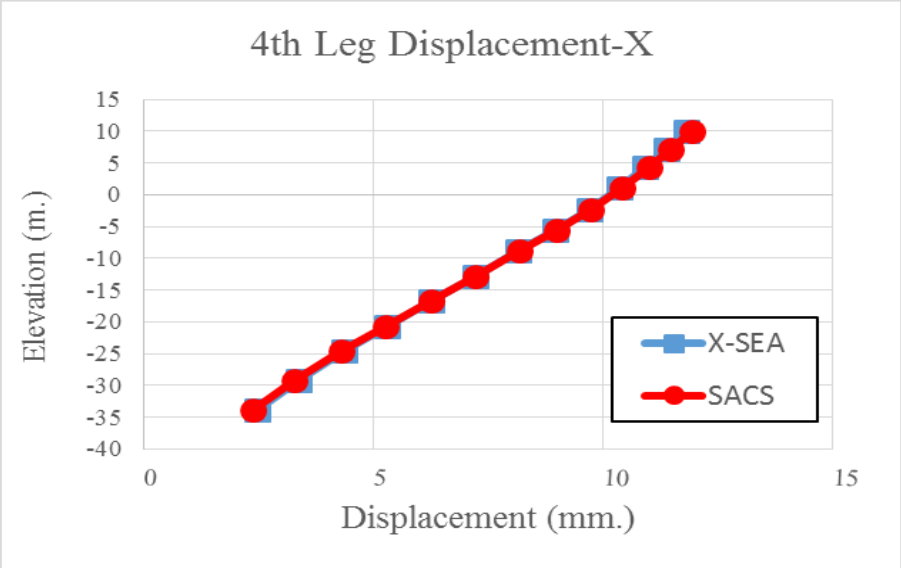

Figure 18. Comparison of X-displacement according to the height of the 4th leg between X-SEA and SACS results using Stoke's wave theory

3.3.4 Member forces

Table 40. Member force of the offshore wind jacket (1st leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Member force from X-SEA (1st leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-17.725	-2.266	0.246	37.522	1.672	-17.574
4.378	-17.253	5.574	7.697	37.611	-15.734	-7.795
1.053	-179.651	-11.918	-24.532	15.390	94.738	-92.506
-2.272	-179.748	5.345	-6.666	15.364	115.976	-75.356
-5.597	-179.823	18.780	7.291	15.345	90.982	-13.363
-8.922	-179.879	29.300	18.262	15.330	29.640	83.739
-12.845	-821.782	-16.165	-1.763	-2.286	40.779	24.454
-16.768	-821.826	-8.690	6.108	-2.299	16.280	-9.976
-20.691	-821.858	-2.904	12.224	-2.309	-32.104	-21.642
-24.614	-821.882	1.651	17.052	-2.315	-99.348	-15.392
-29.242	-1397.210	-2.144	-10.243	-21.733	-44.162	-9.686
-33.87	-1397.230	1.296	-6.593	-21.738	-13.842	-3.919
-38.499	-1397.240	4.154	-3.583	-21.742	2.604	15.083
-43.127	-1397.250	6.639	-0.990	-21.744	7.094	45.583

Table 41. Member force of the offshore wind jacket (1st leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Member force from SACS (1st leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-18.771	2.263	0.060	40.129	-0.069	-18.686
4.378	-18.771	-15.061	17.597	40.129	-21.263	-4.294
1.053	-185.360	3.320	-15.142	16.230	89.653	-87.361
-2.272	-185.360	-12.133	0.614	16.230	112.770	-71.633
-5.597	-185.360	-12.133	0.614	16.230	112.770	-71.633
-8.922	-185.360	-33.730	22.771	16.230	29.117	86.796
-12.845	-835.440	21.341	-6.133	-1.452	34.058	94.156
-16.768	-835.440	12.639	2.860	-1.452	39.706	28.203
-20.691	-835.440	0.779	15.204	-1.452	-35.196	-20.617
-24.614	-835.440	-3.332	19.509	-1.452	-103.670	-15.305
-29.242	-1417.900	4.280	-12.504	-21.783	-95.599	2.511
-33.87	-1417.900	0.412	-8.447	-21.783	-47.424	-8.014
-38.499	-1417.900	-5.355	-2.424	-21.783	1.332	16.386
-43.127	-1417.900	-7.708	0.000	-21.783	6.855	46.728

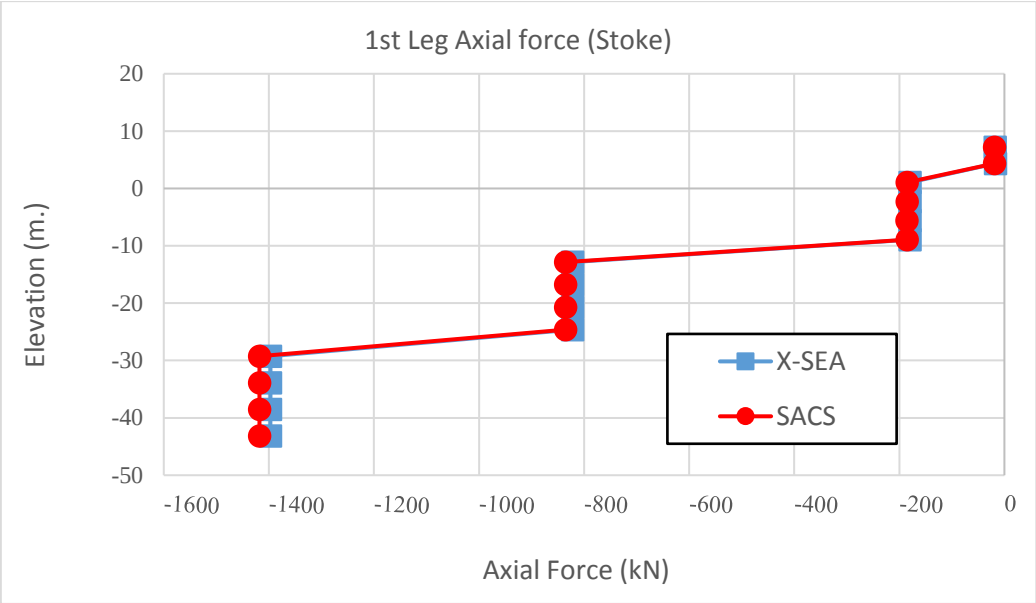

Figure 19. Comparison of axial forces according to the height of the 1st leg between X-SEA and SACS results using Stoke's wave theory

Table 42. Member force of the jacket (2nd leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Member force from X-SEA (2nd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-18.076	-2.371	-0.138	-37.174	-2.061	-17.787
4.378	-17.619	4.348	-7.589	-36.633	14.720	-8.305
1.053	-182.285	-13.040	24.403	-14.665	-96.125	-93.469
-2.272	-182.380	4.504	6.537	-14.802	-116.855	-75.882
-5.597	-182.453	18.152	-7.420	-14.906	-91.371	-13.453
-8.922	-182.508	28.835	-18.392	-14.986	-29.553	84.086
-12.845	-823.126	-16.732	1.749	2.580	-40.788	24.760
-16.768	-823.169	-9.131	-6.122	2.507	-16.191	-9.755
-20.691	-823.199	-3.252	-12.239	2.454	32.279	-21.505
-24.614	-823.221	1.370	-17.067	2.415	99.602	-15.338
-29.242	-1397.860	-2.392	10.258	21.920	44.088	-9.589
-33.87	-1397.870	1.094	6.609	21.888	13.717	-3.834
-38.499	-1397.880	3.982	3.598	21.867	-2.787	15.156
-43.127	-1397.890	6.486	1.005	21.853	-7.339	45.644

Table 43. Member force of the offshore wind jacket (2nd leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Member force from SACS (2nd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	-18.127	2.842	0.425	-41.603	-3.121	-21.534
4.378	-18.127	-14.482	-17.111	-41.603	16.703	-8.773
1.053	-183.700	3.220	15.055	-15.845	-89.788	-87.648
-2.272	-183.700	-12.232	-0.700	-15.845	-112.610	-71.590
-5.597	-183.700	-12.232	-0.700	-15.845	-112.610	-71.590
-8.922	-183.700	-33.829	-22.857	-15.845	-28.387	87.499
-12.845	-833.610	21.391	6.175	1.326	-33.515	94.737
-16.768	-833.610	12.690	-2.818	1.326	-39.326	28.586
-20.691	-833.610	0.829	-15.163	1.326	35.249	-20.631
-24.614	-833.610	-3.282	-19.467	1.326	103.560	-15.518
-29.242	-1417.200	4.267	12.497	21.543	95.474	2.346
-33.87	-1417.200	0.399	8.441	21.543	47.328	-8.122
-38.499	-1417.200	0.399	8.441	21.543	47.328	-8.122
-43.127	-1417.200	-7.721	-0.006	21.543	-6.863	46.791

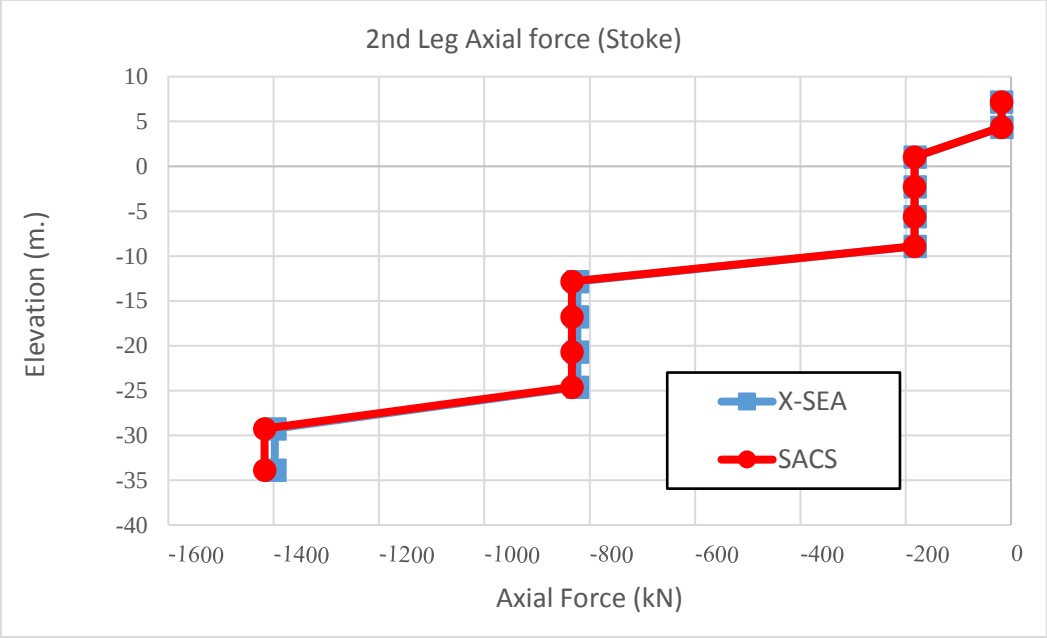

Figure 20. Comparison of axial forces according to the height of the 2nd leg between X-SEA and SACS results using Stoke's wave theory

Table 44. Member force of the jacket (3rd leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Member force from X-SEA (3rd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	12.504	3.508	0.631	29.762	-0.046	27.292
4.378	12.112	-3.382	6.744	29.846	-15.540	22.972
1.053	143.844	10.912	-20.800	10.433	78.770	80.302
-2.272	143.931	-3.747	-6.823	10.414	100.631	68.269
-5.597	143.998	-14.845	3.686	10.399	87.724	19.194
-8.922	144.047	-23.258	11.592	10.388	48.660	-57.963
-12.845	749.484	13.894	2.749	-0.990	41.323	-28.787
-16.768	749.521	8.433	7.789	-1.000	10.314	4.452
-20.691	749.547	4.466	11.406	-1.008	-34.778	22.081
-24.614	749.566	1.570	14.012	-1.013	-90.018	28.318
-29.242	1333.430	0.408	-7.224	-16.084	-47.398	2.621
-33.87	1333.440	-1.355	-5.673	-16.088	-21.276	-3.627
-38.499	1333.450	-2.616	-4.571	-16.091	-0.204	-15.715
-43.127	1333.460	-3.536	-3.757	-16.093	17.135	-32.066

Table 45. Member force of the jacket (3rd leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Member force from SACS (3rd leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	14.317	-3.744	0.233	33.557	3.468	30.005
4.378	14.317	11.208	14.637	33.557	-14.515	22.595
1.053	153.160	-2.999	-13.245	9.666	75.189	75.682
-2.272	153.160	9.787	-1.063	9.666	98.055	63.417
-5.597	153.160	9.787	-1.063	9.666	98.055	63.417
-8.922	153.160	19.524	8.151	9.666	85.539	13.895
-12.845	773.080	-17.794	-0.417	-1.131	50.702	-88.042
-16.768	773.080	-11.289	5.634	-1.131	39.806	-31.613
-20.691	773.080	-3.107	13.121	-1.131	-37.014	21.587
-24.614	773.080	-0.568	15.400	-1.131	-93.250	28.553
-29.242	1364.400	-1.588	-8.483	-16.725	-83.966	0.563
-33.87	1364.400	0.585	-6.554	-16.725	-49.392	2.600
-38.499	1364.400	2.138	-5.186	-16.725	-22.367	-3.902
-43.127	1364.400	4.141	-3.402	-16.725	16.729	-33.838

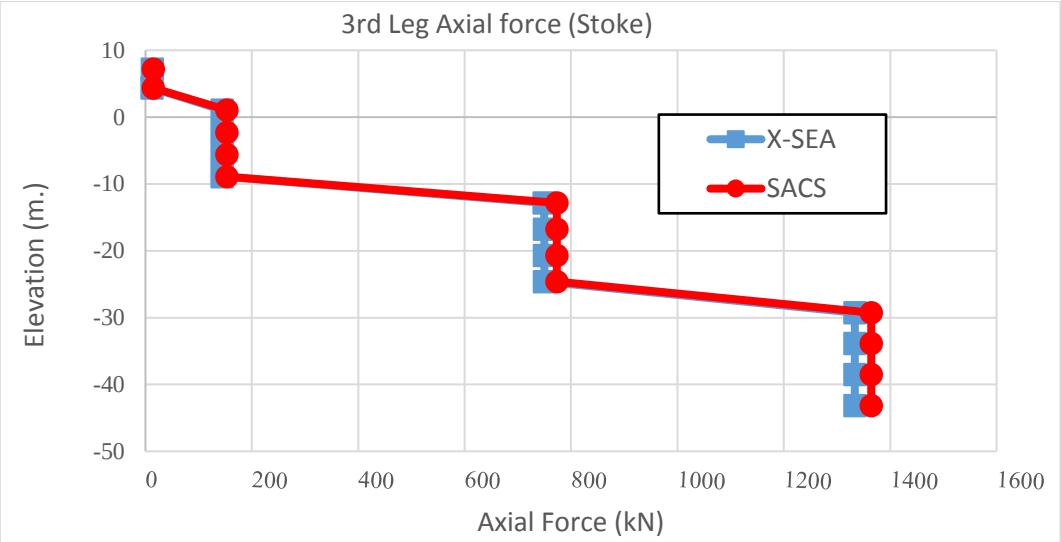

Figure 21. Comparison of axial forces according to the height of the 3rd leg between X-SEA and SACS results using Stoke's wave theory

Table 46. Member force of the offshore wind jacket (4th leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Member force from X-SEA (4th leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	11.585	3.440	-0.630	-30.175	-0.224	27.371
4.378	11.165	-2.468	-6.743	-29.722	15.006	22.860
1.053	140.875	12.118	20.955	-10.033	-77.760	79.324
-2.272	140.967	-2.804	6.978	-10.152	-100.067	67.721
-5.597	141.036	-14.099	-3.532	-10.241	-87.622	19.074
-8.922	141.089	-22.661	-11.437	-10.308	-49.033	-57.653
-12.845	748.780	14.260	-2.774	1.206	-41.735	-28.485
-16.768	748.820	8.687	-7.814	1.146	-10.594	4.585
-20.691	748.848	4.639	-11.431	1.104	34.621	22.045
-24.614	748.869	1.685	-14.037	1.074	89.976	28.113
-29.242	1333.410	0.532	7.227	16.151	47.378	2.646
-33.87	1333.430	-1.270	5.676	16.128	21.258	-3.647
-38.499	1333.440	-2.557	4.574	16.113	0.182	-15.781
-43.127	1333.450	-3.495	3.759	16.103	-17.163	-32.178

Table 47. Member force of the offshore wind jacket (4th leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Member force from SACS (4th leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
7.1962	12.040	-3.698	-0.351	-34.003	-3.134	29.779
4.378	12.040	11.254	-14.755	-34.003	15.180	22.238
1.053	150.540	-3.091	13.340	-10.163	-74.931	75.544
-2.272	150.540	9.694	1.159	-10.163	-98.116	63.585
-5.597	150.540	9.694	1.159	-10.163	-98.116	63.585
-8.922	150.540	19.432	-8.056	-10.163	-85.920	14.371
-12.845	773.140	-17.733	0.347	0.552	-51.492	-87.331
-16.768	773.140	-11.228	-5.703	0.552	-40.324	-31.141
-20.691	773.140	-3.046	-13.190	0.552	37.040	21.577
-24.614	773.140	-0.507	-15.469	0.552	93.548	28.303
-29.242	1365.400	-1.601	8.497	16.308	84.068	0.401
-33.87	1365.400	0.573	6.568	16.308	49.429	2.495
-38.499	1365.400	2.126	5.200	16.308	22.338	-3.950
-43.127	1365.400	4.129	3.416	16.308	-16.889	-33.771

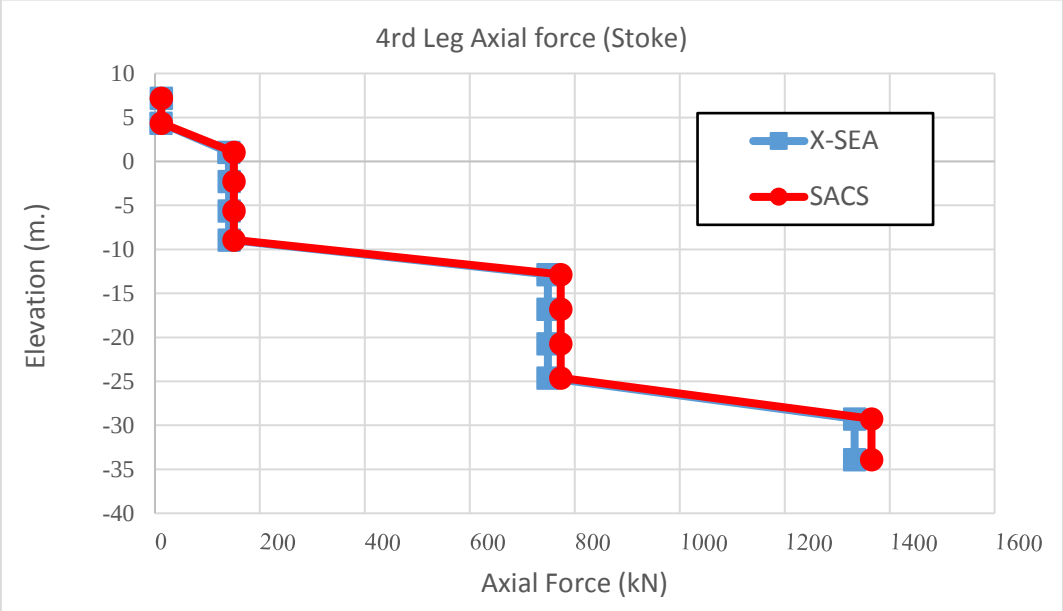

Figure 22. Comparison of axial forces according to the height of the 4th leg between X-SEA and SACS results using Stoke's wave theory