X-SEA VERIFICATION REPORT 3

Offshore Tripod Structures

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01	23/12/2019	Offshore tripod 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 tripod structure subjected to self-weight, Airy's wave, and Stoke's 5th order wave and comparing with the SACS software results. The jacket structure has 50 meters height and three 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.

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Offshore Tripod Structure

1 Introduction

For the verification of X-SEA software, the static analysis of an offshore tripod 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 tripod structure has 50 meters height and three 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 three fixed supports at the bottom of the structure. Displacement and internal forces are compared in each node on a tapper section member and a main leg. All the node positions calculated from the X-SEA and SACS are illustrated in **Figure 1** and **Figure 2**, respectively. There are total 158 nodes and 163 elements in each model.

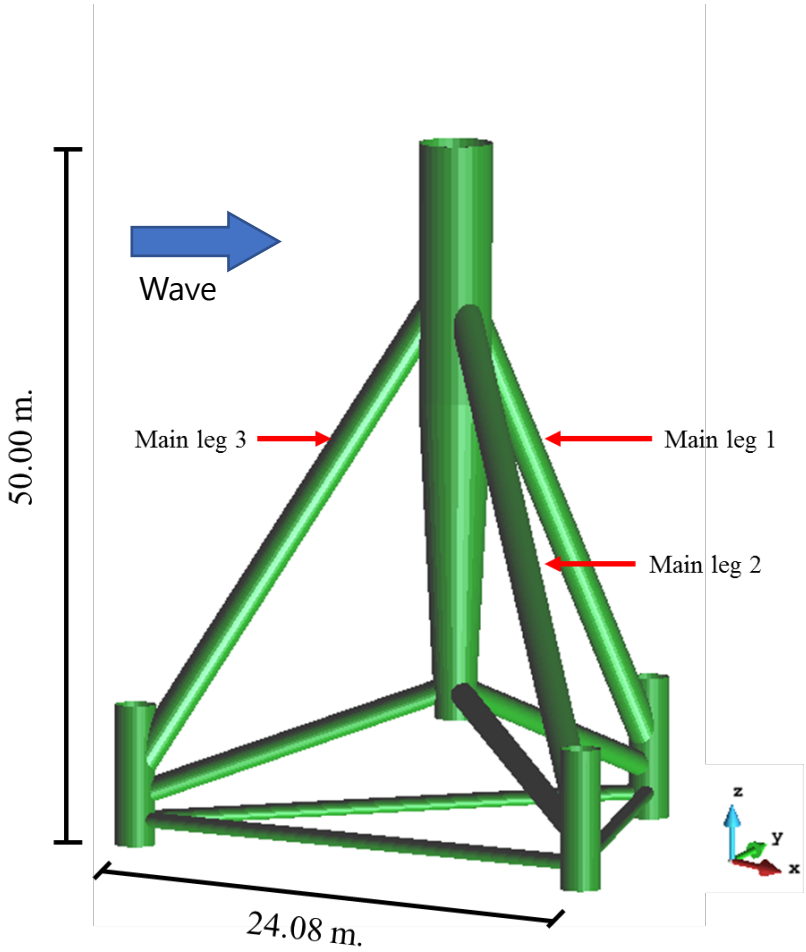

Figure 1. Model of the offshore tripod substructure in X-SEA.

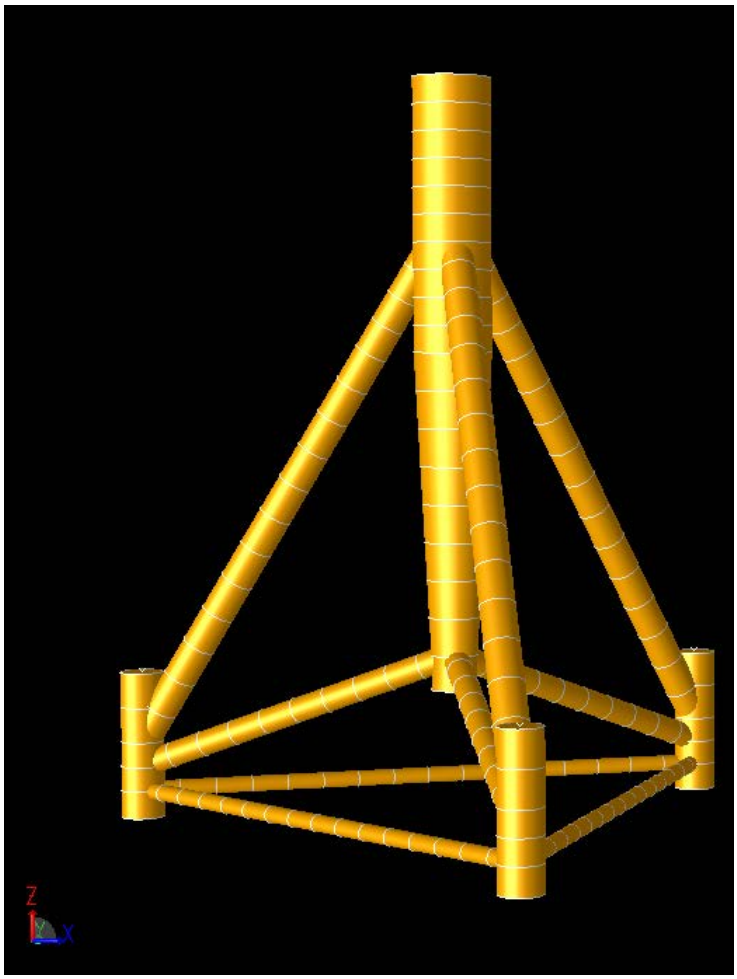

Figure 2. Model of the offshore tripod substructure in SACS.

2 Geometric and Material Properties of Offshore Tripod Structure

The tripod height is 50 m and diameter of the base is 24.08 m. The top section, main legs, bracings and supports of the tripod are in circular hollow sections illustrated in **Figure 3** with their section properties listed in **Table 1**. **Table 2** lists section details of the tapper.

Table 1. Section details of the offshore tripod structure

Section - Circular	Diameter (m.)	Thickness (m.)
Main Leg Type 1	2.475	0.035
Bracing 1	1.875	0.025
Bracing 2	1.200	0.025
Support 1	3.150	0.035
Support 2	3.150	0.045
Top-section	5.700	0.050

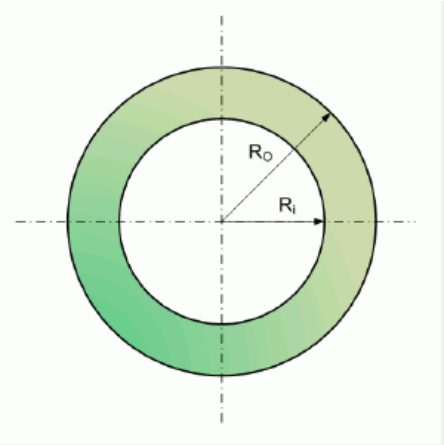

Figure 3. Circular hollow section

Table 2. Section detail of the tapper section

Section - Circular	Diameter (m.)	Thickness (m.)
Taper section (Top)	3.688	0.050
Taper section (Bottom)	5.700	0.050

The material properties of steel for the tripod top, 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.

3 Analysis Results of X-SEA and SACS

3.1 Offshore tripod structure subjected to self-weight loads

The reactions of the tripod 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 offshore tripod 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)
156	-	-	2820.610	-	-	-
157	-	-	2820.610	-	-	-
158	-	-	2820.610	-	-	-

Table 4. Reaction of the offshore tripod 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)
156	-	-	2802.499	-	-	-
157	-	-	2802.499	-	-	-
158	-	-	2802.599	-	-	-

Table 5. Normalized reactions of the offshore tripod 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)
156	-	-	0.994	-	-	-
157	-	-	0.994	-	-	-
158	-	-	0.994	-	-	-

3.2 Offshore tripod structure subjected to Airy's wave

Table 6. Environment condition and Airy's wave parameters

Environment condition	Wave parameter
Water depth = 45.00 m. Sea bed level = -45.00 m. Water density = 1030 kg/m^3 Air Density = 1.25 kg/m^3	Wave theory = Airy wave theory Wave height = 10 m Wave period = 8 seconds

3.2.1 Wave force

Table 7. Wave force due to Airy's wave (tapper section)

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)
-8.00	10.519	-	-	10.525	-	-
-10.00	7.099	-	-	7.290	-	-
-12.77	4.797	-	-	4.934	-	-
-15.55	3.250	-	-	3.363	-	-
-18.32	2.211	-	-	2.302	-	-
-21.09	1.515	-	-	1.579	-	-
-23.87	1.049	-	-	1.087	-	-
-26.64	0.737	-	-	0.776	-	-
-29.42	0.528	-	-	0.558	-	-
-32.19	0.400	-	-	0.420	-	-

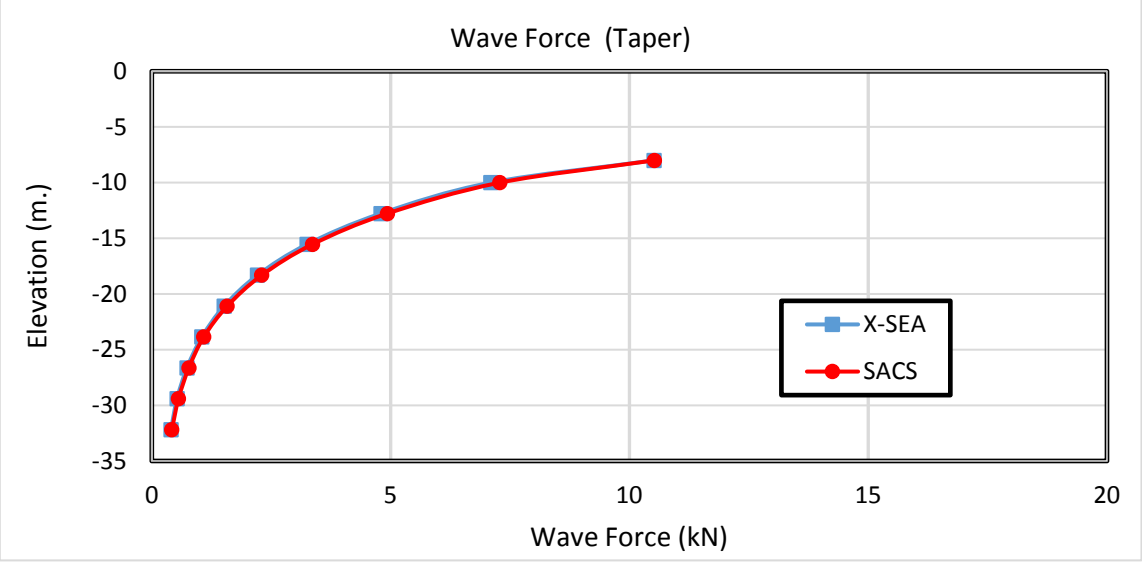

Figure 4. Comparison of wave forces in X-direction according to the height of the tapper section between X-SEA and SACS results using Airy's wave theory

Table 8. Wave force due to Airy's wave (main leg 1)

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)
-2.00	6.787	-	-	6.811	-	-
-4.00	5.731	-	-	5.768	-	-
-6.00	4.914	-	-	4.970	-	-
-8.00	4.281	-	-	4.309	-	-
-10.00	3.790	-	-	3.710	-	-
-12.41	3.337	-	-	3.287	-	-
-14.83	2.997	-	-	2.969	-	-
-17.24	2.737	-	-	2.688	-	-
-19.65	2.536	-	-	2.493	-	-
-22.11	2.374	-	-	2.345	-	-
-24.57	2.247	-	-	2.209	-	-
-27.02	2.148	-	-	2.130	-	-
-29.48	2.073	-	-	2.060	-	-
-31.94	2.022	-	-	2.035	-	-
-34.39	1.996	-	-	2.026	-	-
-36.85	1.996	-	-	2.044	-	-

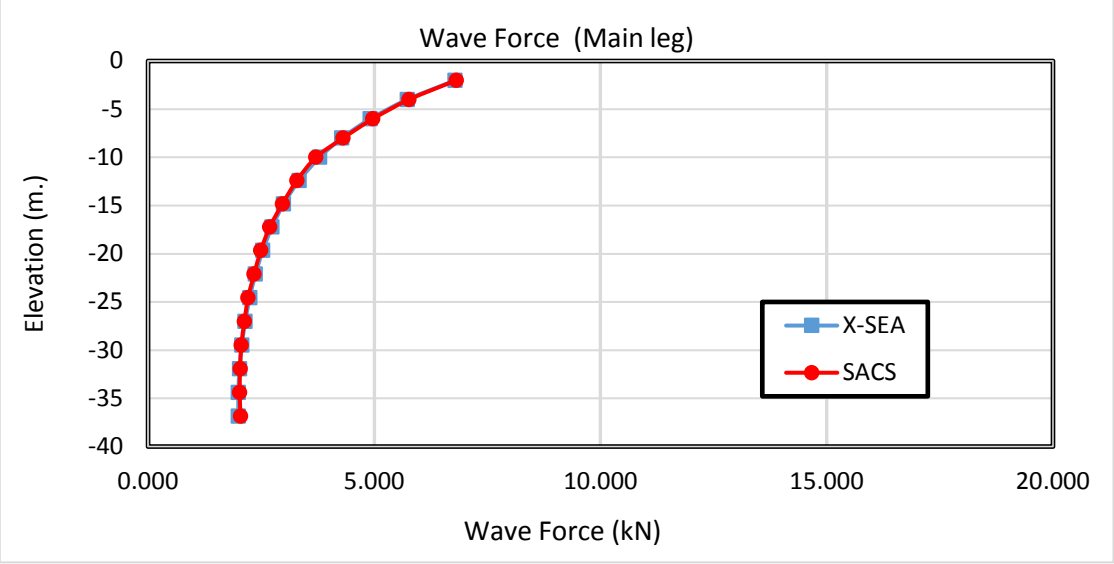

Figure 5. Comparison of wave forces in X-direction according to the height of the main leg 1 between X-SEA and SACS results using Airy's wave theory

3.2.2 Reaction

Table 9. Reactions of the offshore tripod 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)
156	-455.443	0.103	-824.992	-0.319	-2176.170	-2.409
157	-290.534	213.135	524.610	-656.612	-1753.900	365.903
158	-290.487	-213.238	524.617	656.772	-1753.940	-363.097

Table 10. Reaction of the offshore tripod 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)
156	-467.562	0.000	-844.33	0.000	-2159.942	0.000
157	-284.213	234.079	500.351	-739.857	-1751.238	352.86
158	-284.213	-234.078	500.35	739.852	-1751.237	-352.861

Table 11. Normalised solution (X-SEA/SACS) of tripod 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)
156	0.97	-	0.98	-	1.01	-
157	1.02	0.91	1.05	0.89	1.00	1.04
158	1.02	0.91	1.05	0.89	1.00	1.03

3.2.3 Displacement

Table 12. Displacement of the offshore tripod structure (tapper section) by X-SEA using Airy's wave

	Case 1 : Airy ----- Displacement from X-SEA (tapper section)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
-2.000	2.015	0.000	-0.109	0.000	0.027	0.000
-4.000	1.964	0.000	-0.109	0.000	0.030	0.000
-6.000	1.904	0.000	-0.109	0.000	0.033	0.000
-8.000	1.835	0.000	-0.109	0.000	0.037	0.000
-10.000	1.756	0.000	-0.109	0.000	0.041	0.000
-12.774	1.634	0.000	-0.110	0.000	0.046	0.000
-15.547	1.494	0.000	-0.110	0.000	0.051	0.000
-18.321	1.338	0.000	-0.110	0.000	0.057	0.000
-21.094	1.166	0.000	-0.111	0.000	0.062	0.000
-23.868	0.980	0.000	-0.111	0.000	0.066	0.000
-26.641	0.782	0.000	-0.111	0.000	0.070	0.000
-29.415	0.576	0.000	-0.112	0.000	0.070	0.000
-32.188	0.373	0.000	-0.112	0.000	0.068	0.000
-34.713	0.202	0.000	-0.112	0.000	0.068	0.000

Table 13. Displacement of the offshore tripod structure (tapper section) by SACS using Airy's wave theory.

	Case 1 : Airy ----- Displacement from SACS (tapper section)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
-2.000	1.912	0.000	-0.079	0.000	0.000	0.000
-4.000	1.857	0.000	-0.079	0.000	0.000	0.000
-6.000	1.795	0.000	-0.079	0.000	0.000	0.000
-8.000	1.724	0.000	-0.079	0.000	0.000	0.000
-10.000	1.645	0.000	-0.079	0.000	0.000	0.000
-12.774	1.523	0.000	-0.080	0.000	0.000	0.000
-15.547	1.383	0.000	-0.080	0.000	0.001	0.000
-18.321	1.227	0.000	-0.080	0.000	0.001	0.000
-21.094	1.054	0.000	-0.080	0.000	0.001	0.000
-23.868	0.866	0.000	-0.081	0.000	0.001	0.000
-26.641	0.666	0.000	-0.081	0.000	0.001	0.000
-29.415	0.459	0.000	-0.081	0.000	0.001	0.000
-32.188	0.255	0.000	-0.082	0.000	0.001	0.000
-34.713	0.075	0.000	-0.082	0.000	0.001	0.000
-2.000	1.912	0.000	-0.079	0.000	0.000	0.000

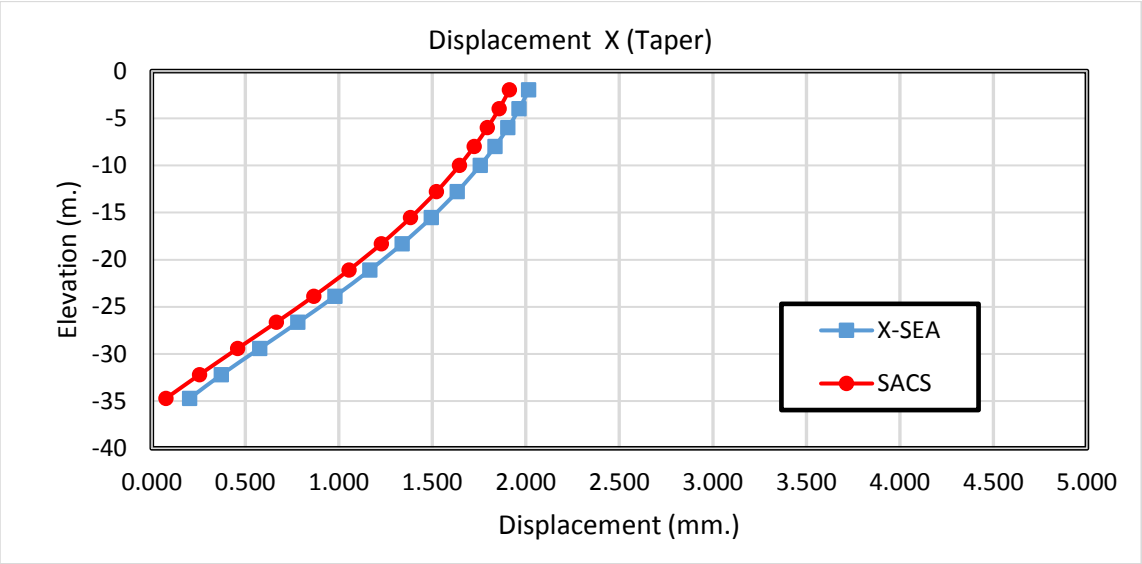

Figure 6. Comparison of X-displacement of the tapper section of the offshore tripod between X-SEA and SACS results using Airy's wave theory according to the height

Table 14. Displacement of the offshore tripod structure (main 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)
-2.000	2.057	-0.081	-0.125	-0.034	0.004	-0.021
-4.000	2.103	-0.220	-0.158	-0.053	-0.009	-0.034
-6.000	2.175	-0.387	-0.198	-0.061	-0.015	-0.039
-8.000	2.253	-0.558	-0.239	-0.060	-0.016	-0.039
-10.000	2.325	-0.715	-0.274	-0.052	-0.013	-0.035
-12.413	2.386	-0.868	-0.304	-0.037	-0.005	-0.025
-14.827	2.406	-0.967	-0.318	-0.018	0.007	-0.013
-17.240	2.375	-1.005	-0.314	0.002	0.021	0.002
-19.654	2.288	-0.981	-0.294	0.022	0.035	0.016
-22.110	2.143	-0.897	-0.260	0.039	0.050	0.030
-24.567	1.943	-0.763	-0.214	0.053	0.063	0.042
-27.023	1.698	-0.592	-0.164	0.061	0.074	0.051
-29.480	1.417	-0.401	-0.113	0.063	0.082	0.056
-31.936	1.118	-0.210	-0.069	0.058	0.085	0.057
-34.393	0.818	-0.042	-0.037	0.045	0.083	0.052
-36.850	0.540	0.079	-0.023	0.024	0.075	0.042
-39.306	0.308	0.128	-0.035	-0.006	0.059	0.024

Table 15. Displacement of offshore tripod (main 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)
-2.000	1.949	-0.050	-0.081	0.000	0.000	0.000
-4.000	1.998	-0.157	-0.096	0.000	0.000	0.000
-6.000	2.080	-0.294	-0.116	-0.001	0.000	0.000
-8.000	2.173	-0.439	-0.138	-0.001	0.000	0.000
-10.000	2.261	-0.577	-0.157	0.000	0.000	0.000
-12.413	2.339	-0.714	-0.173	0.000	0.000	0.000
-14.827	2.373	-0.808	-0.180	0.000	0.000	0.000
-17.240	2.351	-0.848	-0.175	0.000	0.000	0.000
-19.654	2.268	-0.835	-0.159	0.000	0.000	0.000
-22.110	2.121	-0.769	-0.135	0.000	0.001	0.000
-24.567	1.915	-0.659	-0.105	0.000	0.001	0.000
-27.023	1.660	-0.516	-0.072	0.001	0.001	0.001
-29.480	1.367	-0.355	-0.042	0.001	0.001	0.001
-31.936	1.055	-0.196	-0.019	0.000	0.001	0.001
-34.393	0.744	-0.058	-0.007	0.000	0.001	0.001
-36.850	0.458	0.035	-0.011	0.000	0.001	0.000
-39.306	0.227	0.061	-0.035	0.000	0.001	0.000

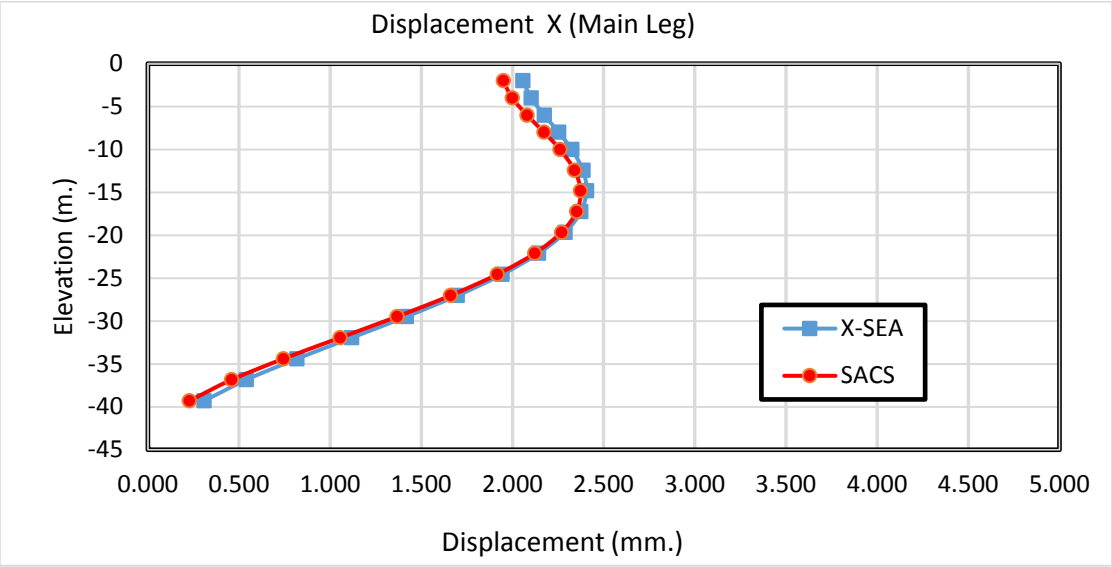

Figure 7. Comparison of X-displacement of the main leg between X-SEA and SACS results using Airy's wave theory according to the height

3.2.4 Member Force

Table 16. Member forces of the offshore tripod (tapper section) by X-SEA model using Airy's wave theory

	Case 1 : Airy ----- Member force from X-SEA (tapper section)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
-8.000	17.085	-12.204	-0.004	-0.003	-0.049	1361.720
-10.000	17.085	-36.547	-0.004	-0.003	-0.037	1262.250
-12.774	17.085	-56.426	-0.004	-0.003	-0.026	1104.310
-15.547	17.085	-69.858	-0.004	-0.003	-0.014	909.593
-18.321	17.085	-78.957	-0.004	-0.003	-0.003	689.956
-21.094	17.085	-85.147	-0.004	-0.003	0.009	453.356
-23.868	17.085	-89.388	-0.004	-0.003	0.020	205.147
-26.641	17.085	-92.322	-0.004	-0.003	0.032	-51.114

Table 17. Member force of the offshore tripod (tapper section) by SACS model using Airy's wave theory

	Case 1 : Airy ----- Member force from SACS (tapper section)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
-8.000	13.914	-50.677	0.000	0.000	0.001	1304.400
-10.000	13.914	-50.677	0.000	0.000	0.001	1304.400
-12.774	13.914	-67.105	0.000	0.000	0.001	1139.800
-15.547	13.914	-78.237	0.000	0.000	0.001	937.400
-18.321	13.914	-85.823	0.000	0.000	0.001	709.330
-21.094	13.914	-91.010	0.000	0.000	0.000	463.730
-23.868	13.914	-97.043	0.000	0.000	0.000	-59.733
-26.641	13.914	-98.812	0.000	0.000	0.000	-331.440

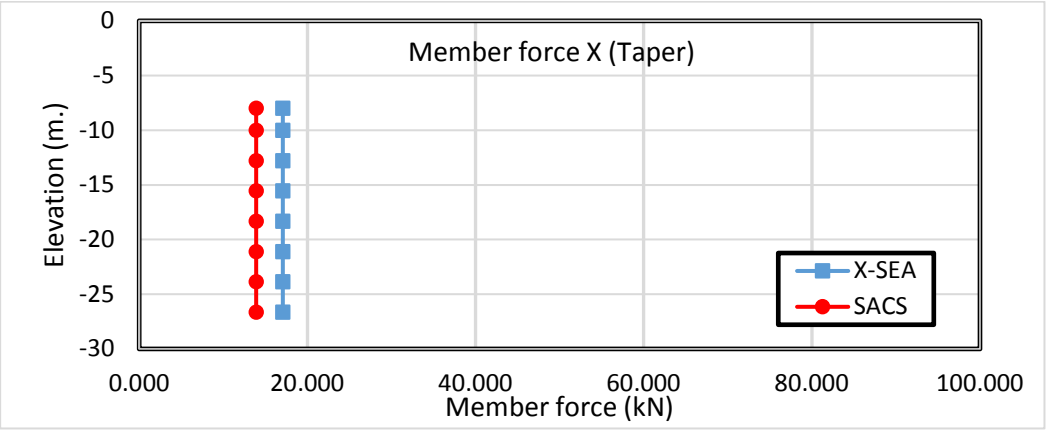

Figure 8. Comparison of axial force of the tapper section between X-SEA and SACS results using Airy's wave theory according to the height

Table 18. Member force of the offshore tripod (main leg) modelled by X-SEA 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)
-2.000	-579.695	62.093	110.946	-0.788	293.407	-117.026
-4.000	-578.430	48.103	88.751	-1.260	84.432	-14.076
-6.000	-577.332	35.929	69.656	-1.630	-79.561	61.524
-8.000	-576.376	25.393	53.069	-1.923	-204.463	113.507
-10.000	-576.498	16.178	37.203	-1.342	-311.934	150.706
-12.413	-575.461	7.034	22.038	-1.660	-374.144	162.652
-14.827	-574.572	-0.438	8.793	-1.895	-398.685	154.868
-17.240	-573.809	-6.398	-2.896	-2.093	-389.971	131.463
-19.654	-573.195	-11.082	-13.399	-2.179	-350.803	95.258
-22.110	-572.608	-14.674	-22.928	-2.307	-283.873	49.697
-24.567	-572.102	-17.233	-31.535	-2.413	-192.003	-2.337
-27.023	-571.663	-18.901	-39.404	-2.497	-77.322	-58.353
-29.480	-571.281	-19.776	-46.653	-2.562	58.381	-116.158
-31.936	-570.944	-19.996	-53.409	-2.609	213.667	-173.924
-34.393	-570.647	-19.531	-59.787	-2.619	387.443	-229.728
-36.850	-570.381	-18.538	-65.886	-2.631	578.898	-282.070

Table 19. Member forces of the offshore tripod (main leg) modelled by SACS 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)
-2.000	-544.390	151.960	44.784	-3.226	-257.220	-896.740
-4.000	-544.390	123.690	37.763	-3.226	-159.580	-571.760
-6.000	-544.390	99.790	30.745	-3.226	-78.605	-308.250
-8.000	-544.390	79.312	23.981	-3.226	-13.965	-97.073
-10.000	-544.390	46.031	11.799	-3.227	69.840	195.810
-12.413	-544.390	29.769	5.546	-3.226	94.368	303.400
-14.827	-544.390	15.637	0.221	-3.227	102.380	367.750
-17.240	-544.390	3.173	-4.194	-3.226	96.497	394.230
-19.654	-544.390	3.174	-4.195	-3.225	96.495	394.230
-22.110	-544.390	-7.877	-7.738	-3.226	79.263	387.200
-24.567	-544.390	-17.915	-10.499	-3.226	52.577	349.490
-27.023	-544.390	-26.985	-12.462	-3.226	19.045	284.070
-29.480	-544.390	-35.232	-13.706	-3.226	-19.123	193.520
-31.936	-544.390	-49.804	-14.262	-3.226	-101.540	-54.547
-34.393	-544.390	-56.387	-13.677	-3.226	-142.250	-208.860
-36.850	-544.390	-62.656	-12.569	-3.227	-180.490	-381.820

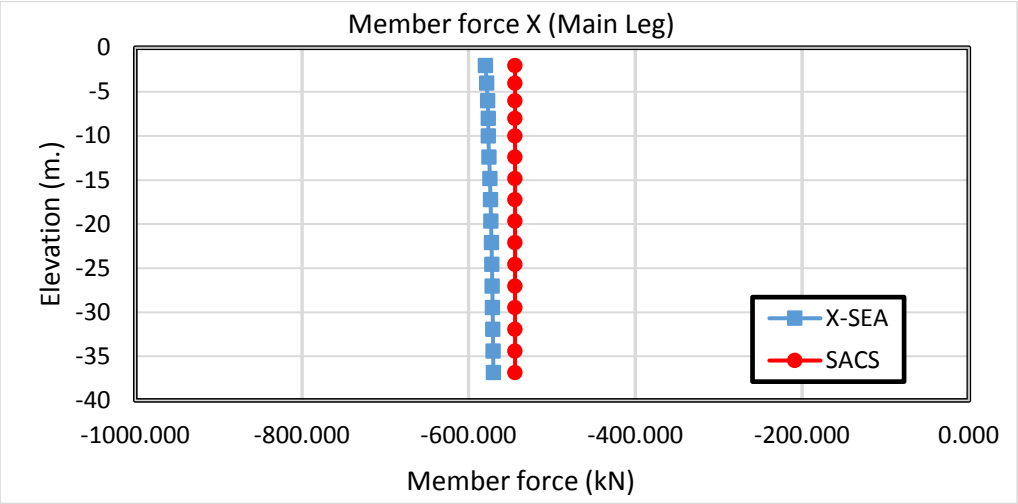

Figure 9. Comparison of axial forces of the main leg between X-SEA and SACS results using Airy's wave theory according to the height

3.3 Offshore tripod structure subjected to Stoke's wave

Table 20. Environment condition and wave parameters

Environment condition	Wave parameter
Water depth = 45.00 m. Sea bed level = -45.00 m. Water density = 1030 kg/m^3 Air Density = 1.25 kg/m^3	Wave theory = **Stoke** wave theory Wave height = 10 m Wave period = 8 seconds

3.3.1 Wave forces

Table 21. Wave forces of offshore tripod (tapper section) due to Stoke's wave

	X-SEA			SACS		
Elevation (m)	F_X(kN)	F_Y(kN)	F_Z(kN)	F_X(kN)	F_Y(kN)	F_Z(kN)
-8.00	9.967	-	-	10.058	-	-
-10.00	6.875	-	-	7.145	-	-
-12.77	4.755	-	-	4.956	-	-
-15.55	3.301	-	-	3.458	-	-
-18.32	2.305	-	-	2.439	-	-
-21.09	1.622	-	-	1.728	-	-
-23.87	1.154	-	-	1.228	-	-
-26.64	0.834	-	-	0.899	-	-
-29.42	0.614	-	-	0.668	-	-
-32.19	0.476	-	-	0.514	-	-

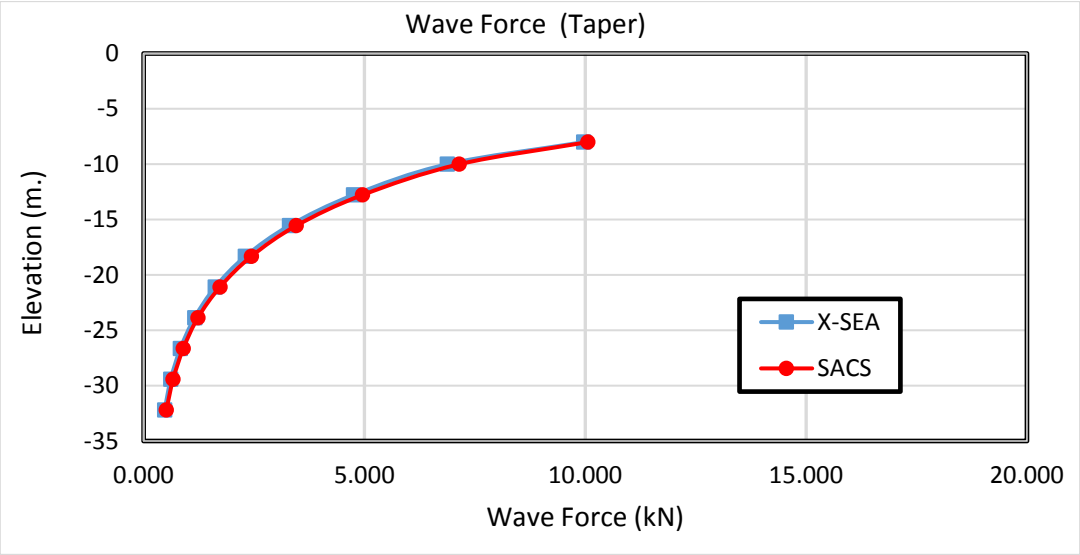

Figure 10. Comparison of wave force in X-direction of tapper section between X-SEA and SACS results using Stoke's wave theory according to the height

Table 22. Wave forces of offshore tripod (main leg) due to Stoke's wave

	X-SEA			SACS		
Elevation (m)	F_X(kN)	F_Y(kN)	F_Z(kN)	F_X(kN)	F_Y(kN)	F_Z(kN)
-2.00	5.740	-	-	5.866	-	-
-4.00	4.962	-	-	5.065	-	-
-6.00	4.350	-	-	4.448	-	-
-8.00	3.867	-	-	3.945	-	-
-10.00	3.486	-	-	3.441	-	-
-12.41	3.129	-	-	3.081	-	-
-14.83	2.856	-	-	2.826	-	-
-17.24	2.646	-	-	2.607	-	-
-19.65	2.483	-	-	2.430	-	-
-22.11	2.354	-	-	2.308	-	-
-24.57	2.254	-	-	2.202	-	-
-27.02	2.179	-	-	2.150	-	-
-29.48	2.128	-	-	2.097	-	-
-31.94	2.099	-	-	2.087	-	-
-34.39	2.093	-	-	2.107	-	-
-36.85	2.113	-	-	2.146	-	-

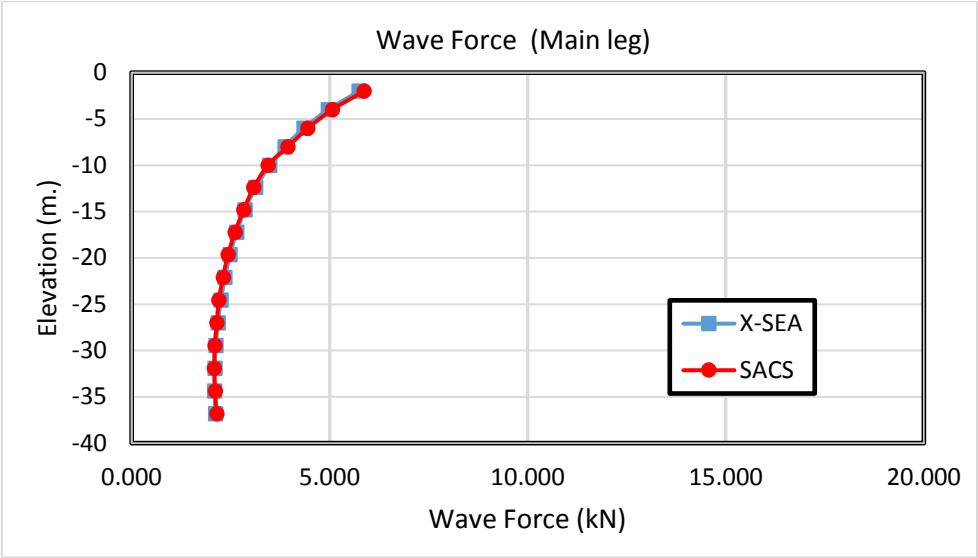

Figure 11. Comparison of wave force in X-direction of offshore tripod (main leg) between X-SEA and SACS results using Stoke's wave theory according to the height

3.3.2 Reaction

Table 23. Reactions of the offshore tripod structure modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- 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)
156	-436.22	0.11	-804.94	-0.34	-2096.22	-2.65
157	-290.26	206.33	516.68	-615.56	-1739.22	369.05
158	-290.21	-206.44	516.69	615.73	-1739.27	-366.06

Table 24. Reactions of the offshore tripod structure modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- 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)
156	-445.482	0.000	-820.701	0.000	-2088.569	0.000
157	-284.485	229.23	495.831	-703.865	-1730.297	354.14
158	-284.485	-229.231	495.832	703.867	-1730.298	-354.14

Table 25. Normalised solution (X-SEA/SACS) of reaction of tripod 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)
156	0.98	-	0.98	-	1.00	-
157	1.02	0.90	1.04	0.87	1.01	1.04
158	1.02	0.90	1.04	0.87	1.01	1.03

3.3.3 Displacement

Table 26. Displacement of the tapper of the offshore tripod modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from X-SEA (tapper section)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
-2.000	1.962	0.000	-0.109	0.000	0.030	0.000
-4.000	1.906	0.000	-0.109	0.000	0.032	0.000
-6.000	1.841	0.000	-0.109	0.000	0.035	0.000
-8.000	1.769	0.000	-0.110	0.000	0.038	0.000
-10.000	1.689	0.000	-0.110	0.000	0.041	0.000
-12.774	1.567	0.000	-0.110	0.000	0.046	0.000
-15.547	1.429	0.000	-0.110	0.000	0.050	0.000
-18.321	1.278	0.000	-0.111	0.000	0.055	0.000
-21.094	1.112	0.000	-0.111	0.000	0.060	0.000
-23.868	0.933	0.000	-0.111	0.000	0.064	0.000
-26.641	0.745	0.000	-0.112	0.000	0.066	0.000
-29.415	0.550	0.000	-0.112	0.000	0.067	0.000
-32.188	0.358	0.000	-0.113	0.000	0.064	0.000
-34.713	0.196	0.000	-0.113	0.000	0.064	0.000

Table 27. Displacement of the tapper of the offshore tripod modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from SACS (tapper section)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
-2.000	1.864	0.000	-0.081	0.000	0.000	0.000
-4.000	1.804	0.000	-0.081	0.000	0.000	0.000
-6.000	1.738	0.000	-0.081	0.000	0.000	0.000
-8.000	1.664	0.000	-0.082	0.000	0.000	0.000
-10.000	1.584	0.000	-0.082	0.000	0.000	0.000
-12.774	1.461	0.000	-0.082	0.000	0.000	0.000
-15.547	1.324	0.000	-0.082	0.000	0.001	0.000
-18.321	1.172	0.000	-0.082	0.000	0.001	0.000
-21.094	1.005	0.000	-0.083	0.000	0.001	0.000
-23.868	0.825	0.000	-0.083	0.000	0.001	0.000
-26.641	0.634	0.000	-0.083	0.000	0.001	0.000
-29.415	0.438	0.000	-0.084	0.000	0.001	0.000
-32.188	0.245	0.000	-0.084	0.000	0.001	0.000
-34.713	0.075	0.000	-0.084	0.000	0.001	0.000
-2.000	1.864	0.000	-0.081	0.000	0.000	0.000

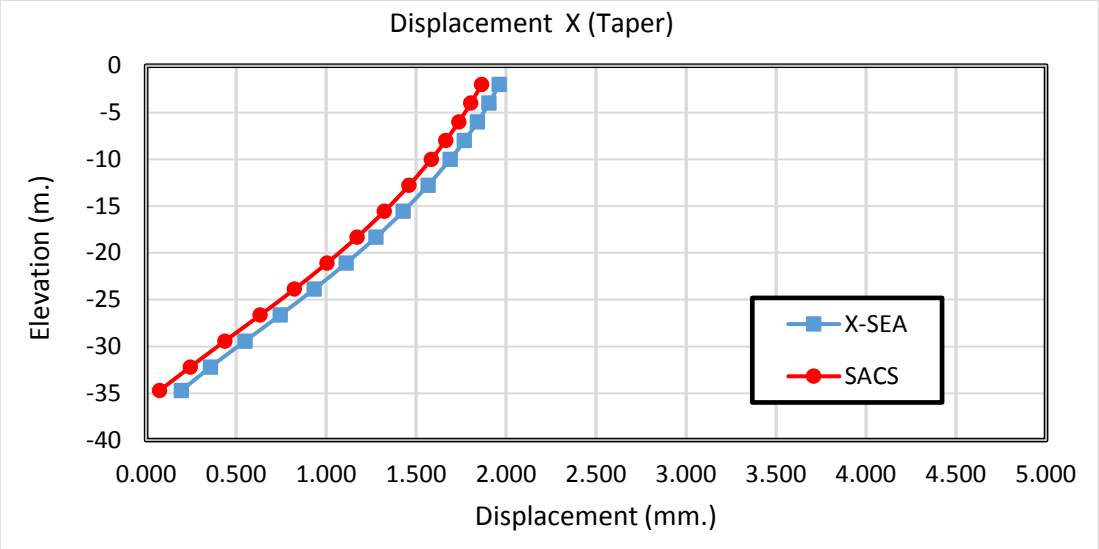

Figure 12. Comparison of X-displacement of the tripod tapper section between X-SEA and SACS results using Stoke's wave theory according to the height

Table 28. Displacement of the offshore tripod (main leg) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from X-SEA (main leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
-2.000	2.000	-0.081	-0.129	-0.034	0.008	-0.021
-4.000	2.036	-0.220	-0.166	-0.053	-0.004	-0.034
-6.000	2.098	-0.387	-0.210	-0.062	-0.011	-0.039
-8.000	2.170	-0.560	-0.254	-0.061	-0.013	-0.040
-10.000	2.236	-0.719	-0.292	-0.053	-0.010	-0.036
-12.413	2.295	-0.875	-0.325	-0.038	-0.004	-0.026
-14.827	2.316	-0.978	-0.341	-0.019	0.007	-0.014
-17.240	2.289	-1.019	-0.339	0.001	0.019	0.000
-19.654	2.210	-0.998	-0.318	0.021	0.033	0.014
-22.110	2.075	-0.916	-0.282	0.039	0.047	0.028
-24.567	1.887	-0.783	-0.235	0.053	0.060	0.040
-27.023	1.654	-0.612	-0.181	0.062	0.071	0.049
-29.480	1.385	-0.420	-0.126	0.064	0.079	0.054
-31.936	1.096	-0.228	-0.078	0.059	0.082	0.055
-34.393	0.805	-0.057	-0.042	0.047	0.081	0.051
-36.850	0.533	0.068	-0.025	0.025	0.073	0.041
-39.306	0.306	0.121	-0.034	-0.004	0.058	0.024

Table 29. Displacement of the offshore tripod (main leg) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Displacement from SACS (main leg)					
Elevation (m)	Dx (mm.)	Dy (mm.)	Dz (mm.)	Rx (rad)	Ry (rad)	Rz (rad)
-2.000	1.899	-0.051	-0.087	0.000	0.000	0.000
-4.000	1.936	-0.159	-0.107	0.000	0.000	0.000
-6.000	2.006	-0.299	-0.133	-0.001	0.000	0.000
-8.000	2.089	-0.448	-0.160	-0.001	0.000	0.000
-10.000	2.168	-0.589	-0.184	0.000	0.000	0.000
-12.413	2.240	-0.731	-0.205	0.000	0.000	0.000
-14.827	2.272	-0.828	-0.214	0.000	0.000	0.000
-17.240	2.253	-0.872	-0.211	0.000	0.000	0.000
-19.654	2.176	-0.861	-0.195	0.000	0.000	0.000
-22.110	2.039	-0.796	-0.168	0.000	0.000	0.000
-24.567	1.845	-0.685	-0.134	0.000	0.001	0.000
-27.023	1.603	-0.540	-0.097	0.001	0.001	0.000
-29.480	1.324	-0.377	-0.061	0.001	0.001	0.001
-31.936	1.025	-0.213	-0.032	0.001	0.001	0.001
-34.393	0.726	-0.071	-0.014	0.000	0.001	0.001
-36.850	0.449	0.027	-0.014	0.000	0.001	0.000
-39.306	0.223	0.056	-0.035	0.000	0.001	0.000

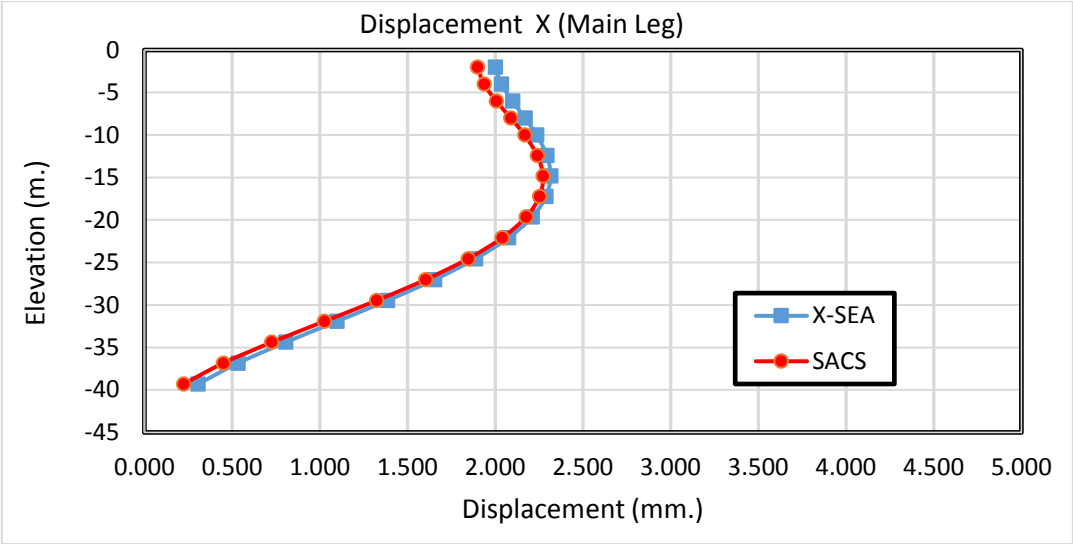

Figure 13. Comparison of X-displacement of the tripod main leg between X-SEA and SACS results using Stoke's wave theory according to the height

3.3.4 Member forces

Table 30. Member force of the offshore tripod (tapper section) modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Member force from X-SEA (tapper section)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
-8.000	18.487	-4.053	-0.004	-0.002	-0.053	1160.060
-10.000	18.487	-27.142	-0.004	-0.002	-0.040	1086.650
-12.774	18.487	-46.371	-0.004	-0.002	-0.028	956.717
-15.547	18.487	-59.668	-0.004	-0.002	-0.015	790.327
-18.321	18.487	-68.899	-0.004	-0.002	-0.003	598.619
-21.094	18.487	-75.342	-0.004	-0.002	0.009	389.229
-23.868	18.487	-79.875	-0.004	-0.002	0.022	167.405
-26.641	18.487	-83.100	-0.004	-0.002	0.034	-63.279

Table 31. Member force of the offshore tripod (tapper section) modelled in SACS using Stoke's wave theory

	Case 2 : Stoke ----- Member force from SACS (tapper section)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
-8.000	14.045	-40.714	0.000	0.000	0.000	1135.700
-10.000	14.045	-40.714	0.000	0.000	0.000	1135.700
-12.774	14.045	-56.983	0.000	0.000	0.000	999.040
-15.547	14.045	-68.276	0.000	0.000	0.000	824.550
-18.321	14.045	-76.177	0.000	0.000	0.000	623.710
-21.094	14.045	-81.749	0.000	0.000	0.000	404.340
-23.868	14.045	-88.523	0.000	0.000	0.000	-69.860
-26.641	14.045	-90.603	0.000	0.000	0.000	-318.370

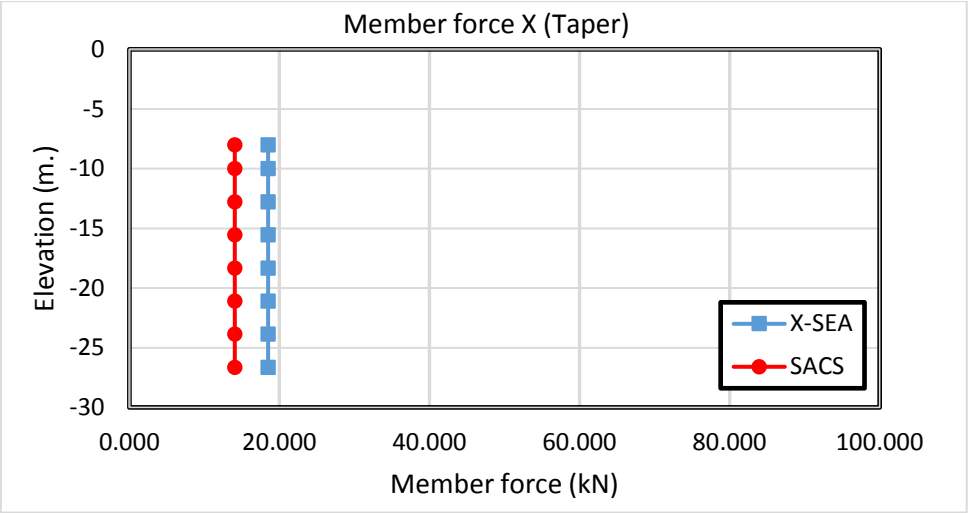

Figure 14. Comparison of axial forces of the tripod tapper between X-SEA and SACS results using Stoke's wave theory according to the height

Table 32. Member force of the tripod main leg modelled in X-SEA using Stoke's wave theory

	Case 2 : Stoke ----- Member force from X-SEA (main leg)					
Elevation (m)	Axial (kN)	Shear-S (kN)	Shear-T (kN)	Torsion (kN)	Moment-S (kN-m)	Moment-T (kN-m)
-2.000	-570.525	64.516	106.242	-2.280	300.772	-118.309
-4.000	-569.279	49.948	85.918	-2.645	98.343	-11.405
-6.000	-568.200	37.331	68.186	-2.938	-62.285	67.187
-8.000	-567.260	26.440	52.583	-3.173	-186.120	121.380
-10.000	-567.408	16.926	37.475	-2.595	-294.356	160.411
-12.413	-566.390	7.473	22.863	-2.860	-358.997	173.315
-14.827	-565.516	-0.275	9.958	-3.057	-386.917	165.726
-17.240	-564.762	-6.491	-1.548	-3.226	-382.090	141.803
-19.654	-564.155	-11.414	-11.987	-3.290	-347.056	104.398
-22.110	-563.568	-15.228	-21.546	-3.399	-284.167	57.014
-24.567	-563.057	-17.984	-30.263	-3.487	-196.014	2.615
-27.023	-562.609	-19.819	-38.308	-3.555	-84.535	-56.211
-29.480	-562.215	-20.824	-45.791	-3.606	48.648	-117.158
-31.936	-561.862	-21.128	-52.833	-3.639	202.249	-178.263
-34.393	-561.548	-20.701	-59.544	-3.636	375.307	-237.462
-36.850	-561.261	-19.693	-66.017	-3.635	567.131	-293.097

Table 33. Member force of the offshore tripod (main 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)
-2.000	-538.050	142.360	52.657	-4.300	-291.930	-867.700
-4.000	-538.050	117.140	43.536	-4.300	-178.290	-561.650
-6.000	-538.050	95.487	34.949	-4.300	-85.600	-310.860
-8.000	-538.050	76.683	27.005	-4.300	-12.480	-107.780
-10.000	-538.050	45.514	13.247	-4.300	81.574	178.240
-12.413	-538.050	29.978	6.343	-4.300	109.270	285.440
-14.827	-538.050	16.365	0.494	-4.301	118.780	351.170
-17.240	-538.050	4.256	-4.353	-4.300	113.040	380.280
-19.654	-538.050	4.258	-4.354	-4.299	113.040	380.280
-22.110	-538.050	-6.603	-8.264	-4.300	94.823	376.660
-24.567	-538.050	-16.559	-11.355	-4.300	66.121	342.770
-27.023	-538.050	-25.603	-13.605	-4.300	29.673	281.340
-29.480	-538.050	-33.894	-15.092	-4.300	-12.180	194.760
-31.936	-538.050	-48.755	-16.003	-4.300	-103.770	-46.269
-34.393	-538.050	-55.537	-15.523	-4.300	-149.700	-197.820
-36.850	-538.050	-62.053	-14.464	-4.301	-193.400	-368.650

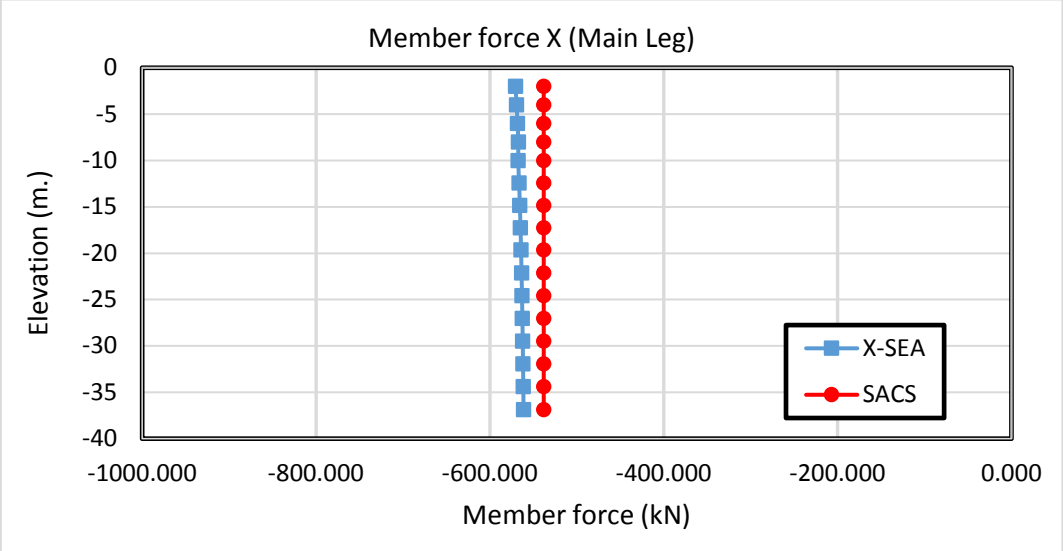

Figure 15. Comparison of axial forces of offshore tripod main leg between X-SEA and SACS results using Stoke's wave theory according to the height