Combined wall structures

QUICK DESIGN TABLES

Combined wall is a retaining wall solution when high horizontal or vertical bearing resistance is required. A combined wall combines pipes (primary elements) with intermediate sheet piles (secondary elements). Pre-calculated tables in this manual offer an easy and quick way to select a combined wall structure with adequate resistance for project.

Applications:
- harbor quay walls
- structures under combined lateral and vertical loads

COMBINED WALL WITH TUBULAR PILES

SSAB supplies spirally welded tubular piles from its mill in Oulainen (FI) delivered with EN 10219 certification and ETA approval as bearing piles. Spirally welded piles can be delivered with diameters up to 1220 mm, wall thicknesses up to 23 mm and lengths up to 39 m without splice welding. Longer piles can be spliced by welding on factory conditions.

Tubular piles are available in numerous European and US steel grades. Most commonly used steel grades, their chemical compositions and mechanical properties are presented in Table 1. Steel and coils are produced in SSAB's own steel mill in Raahe (FI). The piles can be coated on request and are provided with connectors upon customers need. Most often used connector types are E21 and E22. Tubular piles are the main retaining elements of the combined wall, carrying horizontal loads from soil and water pressures and vertical foundation loads. The intermediary sheet piles can be either U-type or Z-type. Sheet piles transfer horizontal loads to the tubular piles. The tables below give an overview of some of the possible combined wall systems. The tables are valid for E21 connectors.

Equivalent moment of inertia and elastic section modulus of combined wall

The design of combined walls is based on guide lines given in EN 1993-5 and it's based on functionality of primary and secondary elements:

- the primary elements act as retaining elements against the earth and water pressures and may act as bearing piles for vertical loads;
- the secondary elements only fill the gap between the primary elements and transmit the loads resulting from earth and water pressures to the primary elements.

This leads to following equations:

$$I_{sys} = \frac{I_{primary\ element}}{b_{sys}}$$

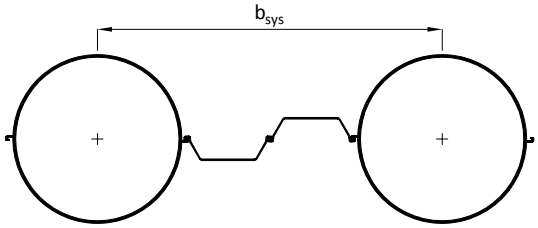
$$W_{sys} = \frac{W_{primary\ element}}{b_{sys}}$$

Table 1. Standard steel grades of SSAB's steel piles. Against special order, the piles may also be delivered in MH steel grades according to standard EN 10219 or X grades according to API5L.

Steel grade	Carbon equivalent	Chemical composition, max.				Mechanical properties				
									Impact strength	
	CEV max. [%]	C [%]	Mn [%]	P [%]	S [%]	f_y min [MPa]	f_u [MPa]	A_5 min [%]	*T**) [°C]	*KV* min [J]
S355J2H	0,45	0,22	1,6	0,03	0,03	355	470-630	20	-20	27
S440J2H	0,45	0,16	1,6	0,02	0,02	440	490-630	17	-20	27
S550J2H	0,47	0,12	1,9	0,02	0,02	550	605-760	14	-20	27

*) Testing temperature may also be -40 °C. Demanded impact energy remains the same.

Table 2. Combined walls with double U sheet piles as secondary elements, width of single sheet pile 600 mm



b_{sys} [m]: System width
$G_{60\%}$: Length of sheet piles is 60 % of length of king piles
$G_{100\%}$: Length of sheet piles is 100 % of length of king piles
I_{sys} [cm⁴/m]: Moment of inertia of combined wall
W_{sys} [cm³/m]: Elastic section modulus of combined wall
M_{el} [kNm/m]: Bending moment resistance with specified steel grade

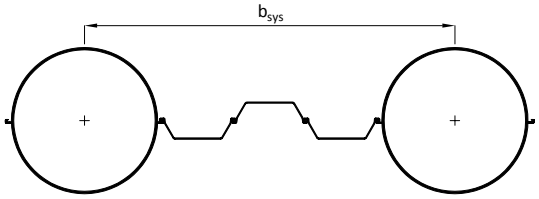
Primary element dimensions			Secondary elements = Double VL603							
Pile	Diameter [mm]	Thickness [mm]	b_{sys} [m]	$G_{60\%}$ [kg/m²]	$G_{100\%}$ [kg/m²]	I_{sys} [cm⁴/m]	W_{sys} [cm³/m]	$M_{el,S355}$ [kNm/m]	$M_{el,S440}$ [kNm/m]	$M_{el,S550}$ [kNm/m]
RR400	406.4	8	1.676	97	131	11 855	583	207	207 *	250 *
		10	1.676	109	142	14 600	719	255	316	319 *
		12.5	1.676	123	157	17 914	882	313	388	485
RR450	457.0	8	1.727	100	133	16 472	721	256	251 *	303 *
		10	1.727	113	145	20 319	889	316	391	388 *
		12.5	1.727	128	161	24 983	1 093	388	481	601
RR500	508.0	8	1.778	103	135	22 092	870	248 *	297 *	358 *
		10	1.778	117	148	27 289	1 074	381	381 *	461 *
		12.5	1.778	133	165	33 608	1 323	470	582	588 *
		14.2	1.778	145	177	37 795	1 488	528	655	818
		16 **	1.778	157	188	42 131	1 659	589	730	
RR550	559.0	8	1.829	106	137	28 740	1 028	288 *	345 *	414 *
		10	1.829	120	151	35 539	1 272	451	444 *	536 *
		12.5	1.829	138	169	43 828	1 568	557	690	686 *
		14.2	1.829	151	181	49 333	1 765	627	777	787 *
		16 **	1.829	163	194	55 048	1 970	699	867	
RR600	610.0	8	1.88	108	138	36 463	1 196	330 *	395 *	472 *
		10	1.88	124	154	45 131	1 480	424 *	509 *	613 *
		12.5	1.88	143	173	55 721	1 827	649	651 *	789 *
		14.2	1.88	156	186	62 768	2 058	731	906	907 *
		16	1.88	170	200	70 097	2 298	816	1 011	1 264
		18	1.88	185	215	78 080	2 560	909	1 126	
RR650	660.0	8	1.93	110	140	45 123	1 367	372 *	444 *	529 *
		10	1.93	127	156	55 891	1 694	479 *	575 *	691 *
		12.5	1.93	147	176	69 071	2 093	743	737 *	891 *
		14.2	1.93	161	190	77 857	2 359	838	1 038	1027 *
		16	1.93	175	205	87 006	2 637	936	1 160	1168 *
		18	1.93	191	221	96 989	2 939	1 043	1 293	
RR700	711.0	8	1.981	113	141	55 105	1 550	416 *	494 *	587 *
		10	1.981	130	158	68 300	1 921	537 *	643 *	770 *
		12.5	1.981	151	180	84 474	2 376	844	827 *	998 *
		14.2	1.981	166	194	95 273	2 680	951	952 *	1152 *
		16	1.981	181	210	106 532	2 997	1 064	1 319	1313 *
		18	1.981	198	226	118 834	3 343	1 187	1 471	1491 *
		20	1.981	215	243	130 919	3 683	1 307	1 620	

*) Cross-section class 4, local buckling considered in given value
**) Diameter – wall thickness combination not in normal production, check availability from SSAB sales

Primary element dimensions			Secondary elements = Double VL603							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el.S355}$ [kNm/m]**	**$M_{el.S440}$ [kNm/m]**	**$M_{el.S550}$ [kNm/m]**
RR750	762.0	8	2.032	115	143	66 281	1 740	460 *	546 *	646 *
		10	2.032	133	161	82 199	2 157	596 *	712 *	851 *
		12.5	2.032	155	183	101 738	2 670	765 *	919 *	1107 *
		14.2	2.032	171	198	114 799	3 013	1 070	1059 *	1279 *
		16	2.032	186	214	128 432	3 371	1 197	1 483	1461 *
		18	2.032	204	232	143 345	3 762	1 336	1 655	1661 *
		20	2.032	222	249	158 013	4 147	1 472	1 825	
RR800	813.0	8	2.083	117	144	78 685	1 936	505 *	597 *	704 *
		10	2.083	136	163	97 630	2 402	656 *	782 *	932 *
		12.5	2.083	159	186	120 912	2 974	844 *	1012 *	1216 *
		14.2	2.083	175	202	136 493	3 358	1 192	1168 *	1409 *
		16	2.083	192	219	152 771	3 758	1 334	1332 *	1611 *
		18	2.083	210	237	170 595	4 197	1 490	1 847	1834 *
		20	2.083	228	255	188 147	4 628	1 643	2 037	
		21 ***	2.083	238	265	196 821	4 842	1 719	2 130	
		22 ***	2.083	247	274	205 427	5 054	1 794	2 224	
RR900	914.0	10	2.184	141	167	132 851	2 907	776 *	921 *	1093 *
		12.5	2.184	166	192	164 702	3 604	1003 *	1200 *	1436 *
		14.2	2.184	183	209	186 055	4 071	1157 *	1388 *	1669 *
		16	2.184	201	227	208 398	4 560	1 619	1587 *	1914 *
		18	2.184	221	247	232 905	5 096	1 809	1806 *	2185 *
		20	2.184	241	266	257 079	5 625	1 997	2 475	
		21 ***	2.184	250	276	269 043	5 887	2 090	2 590	
		22 ***	2.184	260	286	280 924	6 147	2 182	2 705	
RR1000	1016.0	10	2.286	146	170	174 912	3 443	898 *	1062 *	1253 *
		12.5	2.286	172	197	217 027	4 272	1167 *	1391 *	1658 *
		14.2	2.286	190	215	245 303	4 829	1349 *	1614 *	1934 *
		16	2.286	210	234	274 925	5 412	1541 *	1850 *	2224 *
		18	2.286	231	255	307 460	6 052	2 149	2110 *	2546 *
		20	2.286	252	277	339 599	6 685	2 373	2369 *	
		21 ***	2.286	262	287	355 521	6 998	2 484	2498 *	
		22 ***	2.286	273	298	371 346	7 310	2 595	3 216	
		23 ***	2.286	283	308	387 072	7 620	2 705	3 353	
RR1200	1220.0	10	2.490	154	176	279 413	4 581	1141 *	1338 *	1562 *
		12.5	2.490	183	206	347 119	5 690	1497 *	1773 *	2097 *
		14.2	2.490	204	226	392 677	6 437	1740 *	2070 *	2462 *
		16	2.490	225	247	440 491	7 221	1995 *	2383 *	2848 *
		18	2.490	248	271	493 110	8 084	2279 *	2730 *	3277 *
		20	2.490	272	294	545 199	8 938	2561 *	3076 *	
		21 ***	2.490	283	306	571 045	9 361	3 323	3249 *	
		22 ***	2.490	295	318	596 761	9 783	3 473	3421 *	
		23 ***	2.490	307	329	622 345	10 202	3 622	3592 *	

*) Cross-section class 4, local buckling considered in given value
***) Wall thickness not in normal production, check availability from SSAB sales

Table 3. Combined walls with triple U sheet piles as secondary elements, width of single sheet piles 600 mm



b_{sys} [m]: System width
$G_{60\%}$: Length of sheet piles is 60 % of length of king piles
$G_{100\%}$: Length of sheet piles is 100 % of length of king piles
I_{sys} [cm⁴/m]: Moment of inertia of combined wall
W_{sys} [cm³/m]: Elastic section modulus of combined wall
M_{el} [kNm/m]: Bending moment resistance with specified steel grade

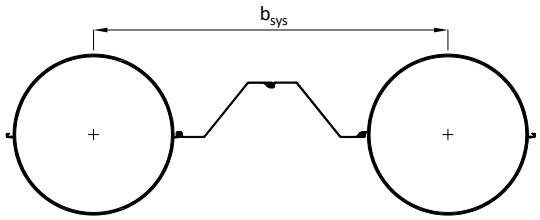
Primary element dimensions			Secondary elements = Triple VL603							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el,S355}$ [kNm/m]**	**$M_{el,S440}$ [kNm/m]**	**$M_{el,S550}$ [kNm/m]**
RR400	406.4	8	2.276	89	125	8 730	430	153	152 *	184 *
		10	2.276	97	133	10 752	529	188	233	235 *
		12.5	2.276	107	143	13 192	649	230	286	357
RR450	457.0	8	2.327	91	126	12 224	535	190	186 *	225 *
		10	2.327	100	136	15 080	660	234	290	288 *
		12.5	2.327	112	147	18 541	811	288	357	446
RR500	508.0	8	2.378	93	128	16 518	650	185 *	222 *	267 *
		10	2.378	103	138	20 404	803	285	285 *	344 *
		12.5	2.378	116	151	25 128	989	351	435	439 *
		14.2	2.378	124	159	28 258	1 113	395	490	612
		16 **	2.378	133	168	31 501	1 240	440	546	
RR550	559.0	8	2.429	95	129	21 641	774	217 *	260 *	312 *
		10	2.429	106	140	26 760	957	340	334 *	404 *
		12.5	2.429	120	154	33 002	1 181	419	520	517 *
		14.2	2.429	129	163	37 147	1 329	472	585	593 *
		16 **	2.429	139	173	41 450	1 483	526	653	
RR600	610.0	8	2.480	98	131	27 642	906	250 *	299 *	357 *
		10	2.480	109	142	34 212	1 122	321 *	386 *	465 *
		12.5	2.480	124	157	42 240	1 385	492	494 *	598 *
		14.2	2.480	134	167	47 582	1 560	554	686	687 *
		16	2.480	144	177	53 138	1 742	618	767	958
		18	2.480	156	189	59 190	1 941	689	854	
RR650	660.0	8	2.530	100	132	34 422	1 043	284 *	338 *	403 *
		10	2.530	112	144	42 637	1 292	366 *	439 *	527 *
		12.5	2.530	128	160	52 690	1 597	567	563 *	680 *
		14.2	2.530	138	170	59 393	1 800	639	792	783 *
		16	2.530	149	182	66 372	2 011	714	885	891 *
		18	2.530	161	194	73 987	2 242	796	986	
RR700	711.0	8	2.581	101	133	42 295	1 190	319 *	380 *	451 *
		10	2.581	115	146	52 422	1 475	412 *	494 *	591 *
		12.5	2.581	131	163	64 837	1 824	647	635 *	766 *
		14.2	2.581	142	174	73 125	2 057	730	731 *	884 *
		16	2.581	154	186	81 767	2 300	817	1 012	1008 *
		18	2.581	167	199	91 209	2 566	911	1 129	1144 *
		20	2.581	180	212	100 485	2 827	1 003	1 244	

*) Cross-section class 4, local buckling considered in given value
**) Diameter - wall thickness combination not in normal production, check availability from SSAB sales

Primary element dimensions			Secondary elements = Triple VL603							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el.S355}$ [kNm/m]**	**$M_{el.S440}$ [kNm/m]**	**$M_{el.S550}$ [kNm/m]**
RR750	762.0	8	2.632	103	134	51 171	1 343	355 *	421 *	499 *
		10	2.632	117	148	63 461	1 666	460 *	550 *	657 *
		12.5	2.632	135	166	78 545	2 062	591 *	710 *	854 *
		14.2	2.632	146	177	88 629	2 326	826	818 *	988 *
		16	2.632	159	190	99 154	2 602	924	1 145	1128 *
		18	2.632	172	203	110 667	2 905	1 031	1 278	1282 *
		20	2.632	186	217	121 992	3 202	1 137	1 409	
RR800	813.0	8	2.683	105	136	61 089	1 503	392 *	463 *	547 *
		10	2.683	120	150	75 797	1 865	509 *	607 *	724 *
		12.5	2.683	138	168	93 873	2 309	655 *	786 *	944 *
		14.2	2.683	150	181	105 969	2 607	925	907 *	1094 *
		16	2.683	163	194	118 607	2 918	1 036	1034 *	1251 *
		18	2.683	177	208	132 445	3 258	1 157	1 434	1424 *
		20	2.683	192	222	146 071	3 593	1 276	1 581	
		21 ***	2.683	199	229	152 806	3 759	1 334	1 654	
		22 ***	2.683	206	236	159 488	3 923	1 393	1 726	
RR900	914.0	10	2.784	124	154	104 220	2 281	609 *	723 *	857 *
		12.5	2.784	144	174	129 206	2 827	787 *	941 *	1126 *
		14.2	2.784	157	187	145 957	3 194	908 *	1089 *	1309 *
		16	2.784	172	201	163 485	3 577	1 270	1245 *	1502 *
		18	2.784	187	217	182 710	3 998	1 419	1417 *	1714 *
		20	2.784	203	232	201 674	4 413	1 567	1 942	
		21 ***	2.784	210	240	211 059	4 618	1 640	2 032	
		22 ***	2.784	218	248	220 380	4 822	1 712	2 122	
RR1000	1016.0	10	2.886	129	157	138 548	2 727	711 *	841 *	993 *
		12.5	2.886	150	178	171 907	3 384	924 *	1102 *	1314 *
		14.2	2.886	164	193	194 304	3 825	1069 *	1279 *	1532 *
		16	2.886	179	208	217 768	4 287	1221 *	1465 *	1762 *
		18	2.886	196	225	243 539	4 794	1 702	1672 *	2017 *
		20	2.886	213	241	268 997	5 295	1 880	1877 *	
		21 ***	2.886	221	250	281 608	5 543	1 968	1979 *	
		22 ***	2.886	230	258	294 143	5 790	2 056	2 548	
		23 ***	2.886	238	266	306 600	6 035	2 143	2 656	
RR1200	1220.0	10	3.090	136	163	225 158	3 691	919 *	1078 *	1259 *
		12.5	3.090	160	187	279 717	4 586	1207 *	1429 *	1690 *
		14.2	3.090	176	203	316 429	5 187	1402 *	1668 *	1984 *
		16	3.090	194	220	354 958	5 819	1608 *	1920 *	2295 *
		18	3.090	213	239	397 361	6 514	1836 *	2200 *	2641 *
		20	3.090	231	258	439 335	7 202	2064 *	2479 *	
		21 ***	3.090	241	267	460 163	7 544	2 678	2618 *	
		22 ***	3.090	250	277	480 885	7 883	2 799	2756 *	
		23 ***	3.090	260	286	501 501	8 221	2 919	2895 *	

*) Cross-section class 4, local buckling considered in given value
***) Wall thickness not in normal production, check availability from SSAB sales

Table 4. Combined walls with double Z sheet piles as secondary elements, width of single sheet pile 700 mm



b_{sys} [m]: System width
$G_{60\%}$: Length of sheet piles is 60 % of length of king piles
$G_{100\%}$: Length of sheet piles is 100 % of length of king piles
I_{sys} [cm⁴/m]: Moment of inertia of combined wall
W_{sys} [cm³/m]: Elastic section modulus of combined wall
M_{el} [kNm/m]: Bending moment resistance with specified steel grade

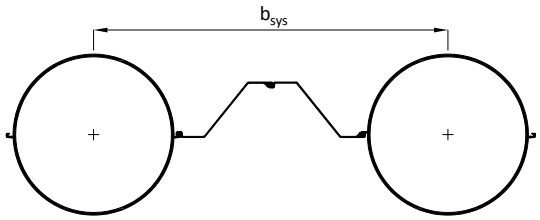
Primary element dimensions			Secondary elements = Double ZZ18-700							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el,S355}$ [kNm/m]**	**$M_{el,S440}$ [kNm/m]**	**$M_{el,S550}$ [kNm/m]**
RR400	406.4	8	2.276	89	125	8 730	430	185	185 *	223 *
		10	2.276	97	133	10 752	529	228	282	285 *
		12.5	2.276	107	143	13 192	649	280	347	433
RR450	457.0	8	2.327	91	126	12 224	535	229	225 *	271 *
		10	2.327	100	136	15 080	660	283	351	348 *
		12.5	2.327	112	147	18 541	811	348	431	539
RR500	508.0	8	2.378	93	128	16 518	650	223 *	267 *	321 *
		10	2.378	103	138	20 404	803	343	342 *	414 *
		12.5	2.378	116	151	25 128	989	422	523	528 *
		14.2	2.378	124	159	28 258	1 113	475	589	736
		16 **	2.378	133	168	31 501	1 240	529	656	
RR550	559.0	8	2.429	95	129	21 641	774	260 *	311 *	373 *
		10	2.429	106	140	26 760	957	407	400 *	483 *
		12.5	2.429	120	154	33 002	1 181	502	622	619 *
		14.2	2.429	129	163	37 147	1 329	565	700	710 *
		16 **	2.429	139	173	41 450	1 483	630	781	
RR600	610.0	8	2.480	98	131	27 642	906	299 *	357 *	426 *
		10	2.480	109	142	34 212	1 122	383 *	460 *	554 *
		12.5	2.480	124	157	42 240	1 385	586	589 *	713 *
		14.2	2.480	134	167	47 582	1 560	660	818	819 *
		16	2.480	144	177	53 138	1 742	737	914	1 142
		18	2.480	156	189	59 190	1 941	821	1 018	
RR650	660.0	8	2.530	100	132	34 422	1 043	337 *	402 *	479 *
		10	2.530	112	144	42 637	1 292	434 *	521 *	626 *
		12.5	2.530	128	160	52 690	1 597	673	668 *	808 *
		14.2	2.530	138	170	59 393	1 800	759	941	930 *
		16	2.530	149	182	66 372	2 011	848	1 051	1059 *
		18	2.530	161	194	73 987	2 242	945	1 172	
RR700	711.0	8	2.581	101	133	42 295	1 190	378 *	449 *	533 *
		10	2.581	115	146	52 422	1 475	488 *	584 *	700 *
		12.5	2.581	131	163	64 837	1 824	766	752 *	907 *
		14.2	2.581	142	174	73 125	2 057	864	864 *	1046 *
		16	2.581	154	186	81 767	2 300	966	1 198	1193 *
		18	2.581	167	199	91 209	2 566	1 078	1 336	1354 *
		20	2.581	180	212	100 485	2 827	1 187	1 472	

*) Cross-section class 4, local buckling considered in given value
**) Diameter - wall thickness combination not in normal production, check availability from SSAB sales

Primary element dimensions			Secondary elements = Double ZZ18-700							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el.S355}$ [kNm/m]**	**$M_{el.S440}$ [kNm/m]**	**$M_{el.S550}$ [kNm/m]**
RR750	762.0	8	2.632	103	134	51 171	1 343	419 *	497 *	588 *
		10	2.632	117	148	63 461	1 666	543 *	648 *	775 *
		12.5	2.632	135	166	78 545	2 062	697 *	837 *	1008 *
		14.2	2.632	146	177	88 629	2 326	974	964 *	1165 *
		16	2.632	159	190	99 154	2 602	1 089	1 350	1330 *
		18	2.632	172	203	110 667	2 905	1 216	1 507	1512 *
		20	2.632	186	217	121 992	3 202	1 340	1 661	
RR800	813.0	8	2.683	105	136	61 089	1 503	460 *	545 *	643 *
		10	2.683	120	150	75 797	1 865	598 *	713 *	851 *
		12.5	2.683	138	168	93 873	2 309	770 *	924 *	1110 *
		14.2	2.683	150	181	105 969	2 607	1 088	1066 *	1285 *
		16	2.683	163	194	118 607	2 918	1 217	1215 *	1470 *
		18	2.683	177	208	132 445	3 258	1 359	1 685	1674 *
		20	2.683	192	222	146 071	3 593	1 499	1 858	
		21 ***	2.683	199	229	152 806	3 759	1 568	1 944	
		22 ***	2.683	206	236	159 488	3 923	1 637	2 029	
RR900	914.0	10	2.784	124	154	104 220	2 281	711 *	844 *	1001 *
		12.5	2.784	144	174	129 206	2 827	919 *	1099 *	1315 *
		14.2	2.784	157	187	145 957	3 194	1060 *	1272 *	1529 *
		16	2.784	172	201	163 485	3 577	1 483	1454 *	1754 *
		18	2.784	187	217	182 710	3 998	1 657	1655 *	2002 *
		20	2.784	203	232	201 674	4 413	1 829	2 268	
		21 ***	2.784	210	240	211 059	4 618	1 915	2 373	
		22 ***	2.784	218	248	220 380	4 822	1 999	2 478	
RR1000	1016.0	10	2.886	129	157	138 548	2 727	826 *	976 *	1152 *
		12.5	2.886	150	178	171 907	3 384	1073 *	1279 *	1525 *
		14.2	2.886	164	193	194 304	3 825	1241 *	1484 *	1778 *
		16	2.886	179	208	217 768	4 287	1417 *	1701 *	2046 *
		18	2.886	196	225	243 539	4 794	1 976	1941 *	2341 *
		20	2.886	213	241	268 997	5 295	2 182	2178 *	
		21 ***	2.886	221	250	281 608	5 543	2 285	2297 *	
		22 ***	2.886	230	258	294 143	5 790	2 386	2 958	
		23 ***	2.886	238	266	306 600	6 035	2 487	3 083	
RR1200	1220.0	10	3.090	136	163	225 158	3 691	1056 *	1238 *	1446 *
		12.5	3.090	160	187	279 717	4 586	1386 *	1642 *	1941 *
		14.2	3.090	176	203	316 429	5 187	1610 *	1916 *	2279 *
		16	3.090	194	220	354 958	5 819	1847 *	2206 *	2637 *
		18	3.090	213	239	397 361	6 514	2109 *	2527 *	3033 *
		20	3.090	231	258	439 335	7 202	2371 *	2848 *	
		21 ***	3.090	241	267	460 163	7 544	3 076	3007 *	
		22 ***	3.090	250	277	480 885	7 883	3 215	3166 *	
		23 ***	3.090	260	286	501 501	8 221	3 353	3325 *	

*) Cross-section class 4, local buckling considered in given value
***) Wall thickness not in normal production, check availability from SSAB sales

Table 5. Combined walls with double Z sheet piles as secondary elements, width of single sheet pile 770 mm



b_{sys} [m]: System width
$G_{60\%}$: Length of sheet piles is 60 % of length of king piles
$G_{100\%}$: Length of sheet piles is 100 % of length of king piles
I_{sys} [cm⁴/m]: Moment of inertia of combined wall
W_{sys} [cm³/m]: Elastic section modulus of combined wall
M_{el} [kNm/m]: Bending moment resistance with specified steel grade

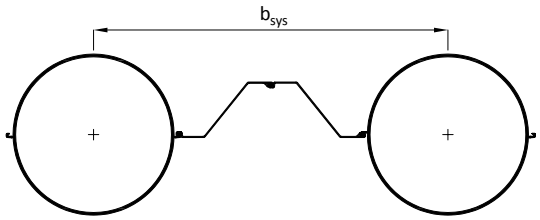
Primary element dimensions			Secondary elements = Double ZZ14-770							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el,S355}$ [kNm/m]**	**$M_{el,S440}$ [kNm/m]**	**$M_{el,S550}$ [kNm/m]**
RR400	406.4	8	2.276	89	125	8 730	430	172	172 *	208 *
		10	2.276	97	133	10 752	529	212	263	265 *
		12.5	2.276	107	143	13 192	649	260	322	403
RR450	457.0	8	2.327	91	126	12 224	535	214	210 *	253 *
		10	2.327	100	136	15 080	660	264	327	324 *
		12.5	2.327	112	147	18 541	811	324	402	502
RR500	508.0	8	2.378	93	128	16 518	650	208 *	250 *	300 *
		10	2.378	103	138	20 404	803	320	320 *	387 *
		12.5	2.378	116	151	25 128	989	394	489	493 *
		14.2	2.378	124	159	28 258	1 113	443	550	687
		16 **	2.378	133	168	31 501	1 240	494	613	
RR550	559.0	8	2.429	95	129	21 641	774	243 *	291 *	349 *
		10	2.429	106	140	26 760	957	381	374 *	452 *
		12.5	2.429	120	154	33 002	1 181	469	582	579 *
		14.2	2.429	129	163	37 147	1 329	528	655	664 *
		16 **	2.429	139	173	41 450	1 483	590	731	
RR600	610.0	8	2.480	98	131	27 642	906	280 *	334 *	399 *
		10	2.480	109	142	34 212	1 122	359 *	431 *	519 *
		12.5	2.480	124	157	42 240	1 385	549	551 *	668 *
		14.2	2.480	134	167	47 582	1 560	619	767	768 *
		16	2.480	144	177	53 138	1 742	691	856	1 070
		18	2.480	156	189	59 190	1 941	770	954	
RR650	660.0	8	2.530	100	132	34 422	1 043	317 *	377 *	450 *
		10	2.530	112	144	42 637	1 292	408 *	489 *	587 *
		12.5	2.530	128	160	52 690	1 597	632	627 *	758 *
		14.2	2.530	138	170	59 393	1 800	712	883	873 *
		16	2.530	149	182	66 372	2 011	796	986	993 *
		18	2.530	161	194	73 987	2 242	887	1 099	
RR700	711.0	8	2.581	101	133	42 295	1 190	355 *	422 *	501 *
		10	2.581	115	146	52 422	1 475	459 *	549 *	658 *
		12.5	2.581	131	163	64 837	1 824	720	706 *	852 *
		14.2	2.581	142	174	73 125	2 057	812	812 *	983 *
		16	2.581	154	186	81 767	2 300	908	1 125	1121 *
		18	2.581	167	199	91 209	2 566	1 013	1 255	1272 *
		20	2.581	180	212	100 485	2 827	1 116	1 383	

*) Cross-section class 4, local buckling considered in given value
**) Diameter - wall thickness combination not in normal production, check availability from SSAB sales

Primary element dimensions			Secondary elements = Double ZZ14-770							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el.S355}$ [kNm/m]**	**$M_{el.S440}$ [kNm/m]**	**$M_{el.S550}$ [kNm/m]**
RR750	762.0	8	2.632	103	134	51 171	1 343	394 *	467 *	553 *
		10	2.632	117	148	63 461	1 666	511 *	610 *	729 *
		12.5	2.632	135	166	78 545	2 062	656 *	787 *	948 *
		14.2	2.632	146	177	88 629	2 326	916	907 *	1096 *
		16	2.632	159	190	99 154	2 602	1 025	1 271	1252 *
		18	2.632	172	203	110 667	2 905	1 144	1 418	1423 *
		20	2.632	186	217	121 992	3 202	1 261	1 563	
RR800	813.0	8	2.683	105	136	61 089	1 503	434 *	513 *	606 *
		10	2.683	120	150	75 797	1 865	564 *	672 *	801 *
		12.5	2.683	138	168	93 873	2 309	726 *	870 *	1046 *
		14.2	2.683	150	181	105 969	2 607	1 025	1004 *	1211 *
		16	2.683	163	194	118 607	2 918	1 147	1145 *	1385 *
		18	2.683	177	208	132 445	3 258	1 281	1 587	1577 *
		20	2.683	192	222	146 071	3 593	1 413	1 751	
		21 ***	2.683	199	229	152 806	3 759	1 478	1 831	
		22 ***	2.683	206	236	159 488	3 923	1 542	1 912	
RR900	914.0	10	2.784	124	154	104 220	2 281	671 *	797 *	946 *
		12.5	2.784	144	174	129 206	2 827	868 *	1038 *	1242 *
		14.2	2.784	157	187	145 957	3 194	1001 *	1201 *	1444 *
		16	2.784	172	201	163 485	3 577	1 401	1373 *	1656 *
		18	2.784	187	217	182 710	3 998	1 566	1563 *	1891 *
		20	2.784	203	232	201 674	4 413	1 728	2 142	
		21 ***	2.784	210	240	211 059	4 618	1 808	2 241	
		22 ***	2.784	218	248	220 380	4 822	1 888	2 340	
RR1000	1016.0	10	2.886	129	157	138 548	2 727	782 *	924 *	1091 *
		12.5	2.886	150	178	171 907	3 384	1016 *	1211 *	1444 *
		14.2	2.886	164	193	194 304	3 825	1174 *	1405 *	1683 *
		16	2.886	179	208	217 768	4 287	1342 *	1610 *	1936 *
		18	2.886	196	225	243 539	4 794	1 870	1837 *	2217 *
		20	2.886	213	241	268 997	5 295	2 066	2062 *	
		21 ***	2.886	221	250	281 608	5 543	2 163	2174 *	
		22 ***	2.886	230	258	294 143	5 790	2 259	2 800	
		23 ***	2.886	238	266	306 600	6 035	2 355	2 919	
RR1200	1220.0	10	3.090	136	163	225 158	3 691	1004 *	1177 *	1374 *
		12.5	3.090	160	187	279 717	4 586	1317 *	1560 *	1845 *
		14.2	3.090	176	203	316 429	5 187	1531 *	1821 *	2166 *
		16	3.090	194	220	354 958	5 819	1756 *	2097 *	2506 *
		18	3.090	213	239	397 361	6 514	2005 *	2402 *	2883 *
		20	3.090	231	258	439 335	7 202	2253 *	2707 *	
		21 ***	3.090	241	267	460 163	7 544	2 924	2858 *	
		22 ***	3.090	250	277	480 885	7 883	3 056	3010 *	
		23 ***	3.090	260	286	501 501	8 221	3 187	3161 *	

*) Cross-section class 4, local buckling considered in given value
***) Wall thickness not in normal production, check availability from SSAB sales

Table 6. Combined walls with double Z sheet piles as secondary elements, width of single sheet pile 800 mm



b_{sys} [m]: System width
$G_{60\%}$: Length of sheet piles is 60 % of length of king piles
$G_{100\%}$: Length of sheet piles is 100 % of length of king piles
I_{sys} [cm⁴/m]: Moment of inertia of combined wall
W_{sys} [cm³/m]: Elastic section modulus of combined wall
M_{el} [kNm/m]: Bending moment resistance with specified steel grade

Primary element dimensions			Secondary elements = Double AZ18-800							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el,S355}$ [kNm/m]**	**$M_{el,S440}$ [kNm/m]**	**$M_{el,S550}$ [kNm/m]**
RR400	406.4	8	2.276	89	125	8 730	430	167	167 *	202 *
		10	2.276	97	133	10 752	529	206	255	258 *
		12.5	2.276	107	143	13 192	649	253	313	391
RR450	457.0	8	2.327	91	126	12 224	535	208	204 *	246 *
		10	2.327	100	136	15 080	660	256	318	315 *
		12.5	2.327	112	147	18 541	811	315	391	488
RR500	508.0	8	2.378	93	128	16 518	650	202 *	243 *	292 *
		10	2.378	103	138	20 404	803	311	311 *	376 *
		12.5	2.378	116	151	25 128	989	383	475	480 *
		14.2	2.378	124	159	28 258	1 113	431	534	668
		16 **	2.378	133	168	31 501	1 240	481	596	
RR550	559.0	8	2.429	95	129	21 641	774	237 *	283 *	340 *
		10	2.429	106	140	26 760	957	370	364 *	440 *
		12.5	2.429	120	154	33 002	1 181	457	566	563 *
		14.2	2.429	129	163	37 147	1 329	514	637	646 *
		16 **	2.429	139	173	41 450	1 483	574	711	
RR600	610.0	8	2.480	98	131	27 642	906	272 *	325 *	389 *
		10	2.480	109	142	34 212	1 122	350 *	420 *	506 *
		12.5	2.480	124	157	42 240	1 385	535	537 *	650 *
		14.2	2.480	134	167	47 582	1 560	602	747	747 *
		16	2.480	144	177	53 138	1 742	673	834	1 042
		18	2.480	156	189	59 190	1 941	749	929	
RR650	660.0	8	2.530	100	132	34 422	1 043	308 *	368 *	438 *
		10	2.530	112	144	42 637	1 292	397 *	476 *	572 *
		12.5	2.530	128	160	52 690	1 597	615	611 *	738 *
		14.2	2.530	138	170	59 393	1 800	694	860	850 *
		16	2.530	149	182	66 372	2 011	775	961	968 *
		18	2.530	161	194	73 987	2 242	864	1 071	
RR700	711.0	8	2.581	101	133	42 295	1 190	346 *	411 *	489 *
		10	2.581	115	146	52 422	1 475	447 *	535 *	641 *
		12.5	2.581	131	163	64 837	1 824	702	688 *	831 *
		14.2	2.581	142	174	73 125	2 057	792	792 *	958 *
		16	2.581	154	186	81 767	2 300	885	1 097	1093 *
		18	2.581	167	199	91 209	2 566	987	1 224	1240 *
		20	2.581	180	212	100 485	2 827	1 088	1 348	

*) Cross-section class 4, local buckling considered in given value
**) Diameter - wall thickness combination not in normal production, check availability from SSAB sales

Primary element dimensions			Secondary elements = Double AZ18-800							
Pile	**Diameter [mm]**	**Thickness [mm]**	**b_{sys} [m]**	**$G_{60\%}$ [kg/m²]**	**$G_{100\%}$ [kg/m²]**	**I_{sys} [cm⁴/m]**	**W_{sys} [cm³/m]**	**$M_{el.S355}$ [kNm/m]**	**$M_{el.S440}$ [kNm/m]**	**$M_{el.S550}$ [kNm/m]**
RR750	762.0	8	2.632	103	134	51 171	1 343	384 *	456 *	540 *
		10	2.632	117	148	63 461	1 666	498 *	595 *	711 *
		12.5	2.632	135	166	78 545	2 062	639 *	768 *	925 *
		14.2	2.632	146	177	88 629	2 326	894	885 *	1069 *
		16	2.632	159	190	99 154	2 602	1 000	1 239	1221 *
		18	2.632	172	203	110 667	2 905	1 116	1 383	1388 *
		20	2.632	186	217	121 992	3 202	1 230	1 525	
RR800	813.0	8	2.683	105	136	61 089	1 503	423 *	501 *	591 *
		10	2.683	120	150	75 797	1 865	550 *	656 *	782 *
		12.5	2.683	138	168	93 873	2 309	708 *	849 *	1021 *
		14.2	2.683	150	181	105 969	2 607	1 000	980 *	1182 *
		16	2.683	163	194	118 607	2 918	1 119	1117 *	1352 *
		18	2.683	177	208	132 445	3 258	1 250	1 549	1539 *
		20	2.683	192	222	146 071	3 593	1 378	1 708	
		21 ***	2.683	199	229	152 806	3 759	1 442	1 787	
		22 ***	2.683	206	236	159 488	3 923	1 505	1 865	
RR900	914.0	10	2.784	124	154	104 220	2 281	656 *	778 *	
		12.5	2.784	144	174	129 206	2 827	848 *	1014 *	1214 *
		14.2	2.784	157	187	145 957	3 194	978 *	1173 *	1410 *
		16	2.784	172	201	163 485	3 577	1 368	1341 *	1618 *
		18	2.784	187	217	182 710	3 998	1 529	1527 *	1847 *
		20	2.784	203	232	201 674	4 413	1 688	2 092	
		21 ***	2.784	210	240	211 059	4 618	1 766	2 189	
		22 ***	2.784	218	248	220 380	4 822	1 844	2 286	
RR1000	1016.0	10	2.886	129	157	138 548	2 727	764 *	904 *	1066 *
		12.5	2.886	150	178	171 907	3 384	993 *	1184 *	1411 *
		14.2	2.886	164	193	194 304	3 825	1148 *	1374 *	1646 *
		16	2.886	179	208	217 768	4 287	1312 *	1574 *	1893 *
		18	2.886	196	225	243 539	4 794	1 829	1796 *	2167 *
		20	2.886	213	241	268 997	5 295	2 020	2016 *	
		21 ***	2.886	221	250	281 608	5 543	2 114	2126 *	
		22 ***	2.886	230	258	294 143	5 790	2 209	2 737	
		23 ***	2.886	238	266	306 600	6 035	2 302	2 853	
RR1200	1220.0	10	3.090	136	163	225 158	3 691	983 *	1153 *	1346 *
		12.5	3.090	160	187	279 717	4 586	1290 *	1528 *	1807 *
		14.2	3.090	176	203	316 429	5 187	1499 *	1783 *	2121 *
		16	3.090	194	220	354 958	5 819	1719 *	2053 *	2454 *
		18	3.090	213	239	397 361	6 514	1963 *	2353 *	2823 *
		20	3.090	231	258	439 335	7 202	2206 *	2651 *	
		21 ***	3.090	241	267	460 163	7 544	2 863	2799 *	
		22 ***	3.090	250	277	480 885	7 883	2 992	2947 *	
		23 ***	3.090	260	286	501 501	8 221	3 121	3095 *	

*) Cross-section class 4, local buckling considered in given value
***) Wall thickness not in normal production, check availability from SSAB sales

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